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PRELIMINARY ASSESSMENT OF HABITAT UTILIZATION BY HAWAIIAN GREEN TURTLES IN THEIR RESIDENT FORAGING PASTURES

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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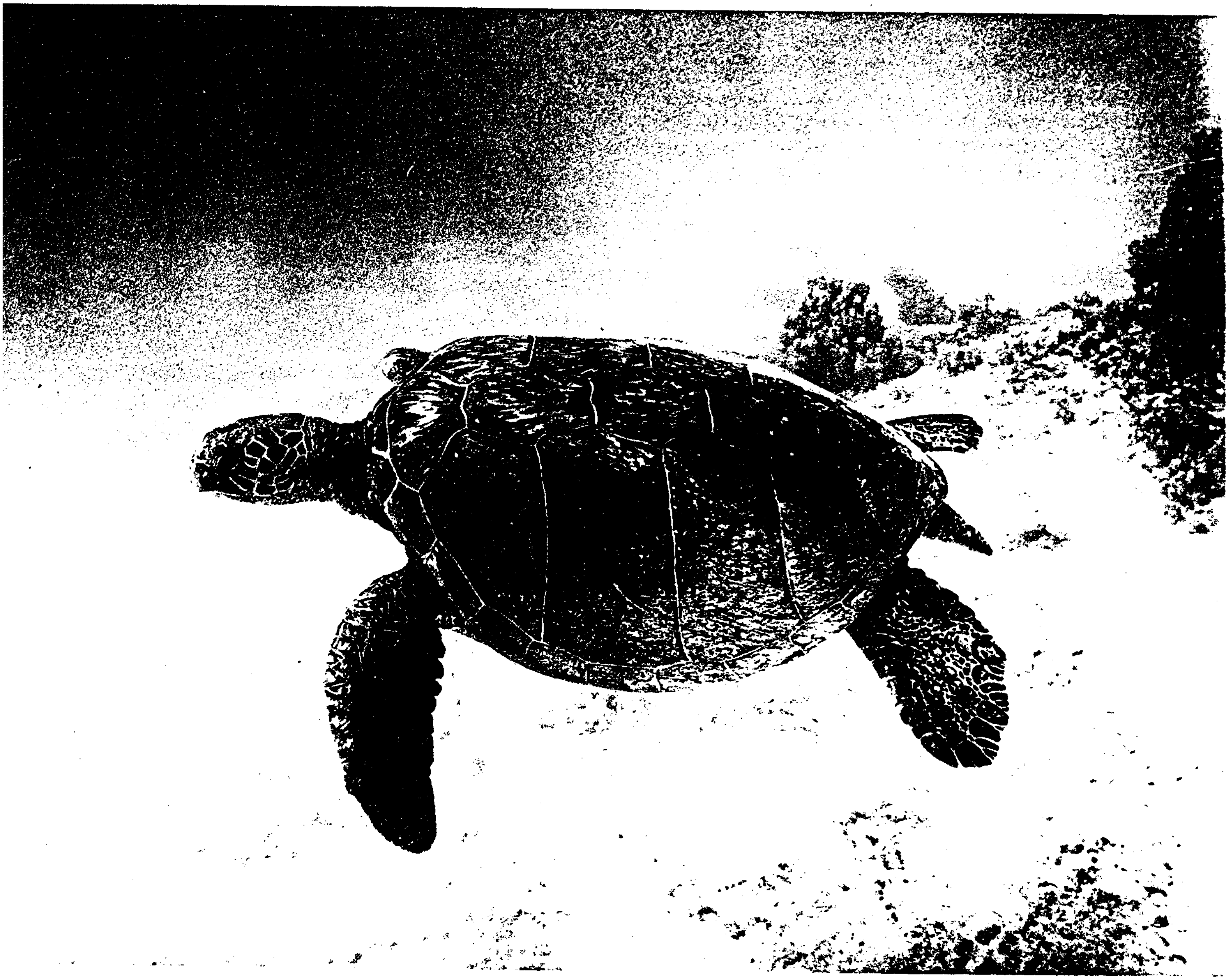

Adult female green turtle in coastal benthic habitat of the main Hawaiian Islands.

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BACKGROUND

The herbivorous Hawaiian green sea turtle, Chelonia mydas, is a long-range migrant breeder that spends most of its life foraging and resting in nearshore benthic habitat. Adult females undertake reproductive migrations at intervals of 2 or more years, while the adult males often migrate to breed on an annual basis. The colonial breeding site for the Hawaiian green turtle is French Frigate Shoals, a cluster of sand islets in the Northwestern Hawaiian Islands situated at lat. 23°45'N, long. 166°10'W, the approximate midpoint of the 2,450 km linear Hawaiian Archipelago. French Frigate Shoals, along with several other sites in the Northwestern Hawaiian Islands, are part of the National Wildlife Refuge System administered by the U.S. Fish and Wildlife Service. Tagging studies have shown that turtles nesting at French Frigate Shoals come from numerous resident foraging areas throughout the Hawaiian Archipelago (Fig. 1).

At least 90% of all reproduction by green turtles in the Hawaiian Islands occurs at French Frigate Shoals. The breeding season at this remote site lasts for about 4 months (May-August) although many turtles, especially males, depart for their resident pastures after only a month or two. Copulation, which precedes nesting, occurs in shallow protected waters close to the islet where the female comes ashore to deposit her eggs. The females lay from one to six egg clutches (mean 1.8) at 11- to 18-day intervals within each season. During the internesting intervals, they actively avoid further mating attempts by males, but remain in shallow water near their nesting beach or, along with males, haul out to rest on the shoreline. Terrestrial basking of this nature is rare among sea turtles, being limited to a few populations of green turtles found exclusively in the Pacific. In Hawaii this behavior is restricted almost entirely to the Northwestern Hawaiian Islands. It is believed to be carried out for thermoregulation, and also possibly for protection from the tiger shark, Galeocerdo cuvieri, an important predator of the green turtle.

Hatchling Hawaiian green turtles measuring 5 cm in carapace length emerge from nests and enter the sea at French Frigate Shoals between July and October. The hatchlings swim immediately away from shore into pelagic habitat where they reside for at least 2 years. During this oceanic phase they are almost never seen, and therefore are not accessible for ecological investigation. Residency is thought to take place at or near the ocean surface, most likely along driftlines or areas where currents converge. Available food sources concentrated in these areas consist of various macroplankton. A combination of ocean currents and a strong swimming ability is believed to account for the turtles' eventual dispersal into nearshore benthic habitat. Turtles <35 cm are virtually never found in coastal waters of the Hawaiian Islands. The 35 cm size class is therefore assumed to be the minimum at which recruitment occurs to nearshore habitat from the pelagic environment. A generalized life history and habitat model for the Hawaiian green turtle is shown in Figure 2.

The eight main and inhabited islands consisting of Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niihau in the southeastern segment of the archipelago (Fig. 1) account for 96% (1,165 km) of the

1,210 km coastline found in Hawaii. Most Hawaiian green turtles from 35 cm juveniles to mature adults >82 cm reside in the nearshore habitat of these eight islands. Factors responsible for this distribution include the greater amount of available habitat, an abundance of certain marine vegetation preferred for food, and oceanic currents that appear favorable in transporting young turtles to the main islands for recruitment into coastal habitat. The benthic habitat surrounding the main islands is, however, limited in scope since great depths generally occur just a few kilometers from shore.

Immature Hawaiian green turtles living in the wild have been found to grow at a slow rate. From 10 to 60 years may be needed to reach sexual maturity (Balazs 1982; Zug and Balazs 1985). Based on 10 years of tagging data, the total number of adult females nesting at French Frigate Shoals has been estimated at approximately 750 (Wetherall 1983). Other major aspects of existing knowledge on the Hawaiian green turtle population have been presented in Balazs (1976, 1978, 1980b, 1983), Dizon and Balazs (1982), and Whittow and Balazs (1982). Along with other sea turtles under United States jurisdiction, the Hawaiian green turtle is listed and protected (since 1978) under provisions of the U.S. Endangered Species Act.

Although green turtles only spend a small portion of their lives on land, most research worldwide has been focused at these sites. This is due to the critical importance of the breeding colony to the overall survival of each population, and also the easy access afforded to relatively large numbers of nesting females, eggs, and hatchlings in the terrestrial environment. Green turtles, like many other highly mobile marine animals, are difficult to study in their underwater habitat. Nevertheless, a knowledge of the habitat requirements for nearshore foraging, resting, and other developmental needs is essential for the conservation and management of the species. The necessity of undertaking habitat-related research in resident foraging pastures has been emphasized repeatedly during recent years (Carr et al. 1978; Carr 1980; Bjorndal 1982; Carr et al. 1982; Shabica 1982; Coston-Clements and Hoss 1983; Hopkins and Richardson 1984).

Studies previously initiated in the main Hawaiian Islands on green turtles in their nearshore habitat have established a foundation for doing more extensive work at this location. Recent studies conducted elsewhere on various aspects of green turtles in their resident foraging pastures include those of Ireland (1979); Bjorndal (1980, 1982, 1985); Mendonca and Ehrhart (1982); Ehrhart (1983); Ogden et al. (1983); Limpus et al. (1984); Frazer and Ehrhart (1985); Limpus and Reed (1985); and Ross (1985). In addition, a comprehensive assessment of green turtle foraging habitat has been accomplished at Johnston Atoll, 830 km to the southwest of the Hawaiian Islands (Balazs 1985b). Along with earlier foraging pasture studies by Hirth and Carr (1970) and Hirth et al. (1973), and the works cited above, the results of the present study will serve as a model for comparative research and should have broad application to a number of geographically separate green turtle populations.

The aim of the study reported herein was to identify and assess, through a series of field surveys, a select number of resident foraging habitats situated along the coastlines of four (Oahu, Molokai, Maui, and Lanai) of the main Hawaiian Islands. The study sites were chosen because of their interesting or representative ecology, the presence of substantial numbers of turtles, and/or the historical prominence of the site as it relates to green turtles.

ASSESSMENT METHODS

Field studies totaling 74 days were conducted between February and November 1985 to accomplish the assessment (Table 1). The three principal study sites focused upon were Kawela Bay on Oahu, Palaau on Molokai, and Kahului Bay on Maui. Selection of these locations resulted from previous exploratory surveys, as well as information obtained from interviews with fishermen and other local residents indicating high concentrations of turtles. The presence of turtles in prominent numbers was used as an indicator that the habitat fulfilled the animals foraging and resting requirements. An additional nine other sites, listed in Table 1, were chosen for less intense appraisal. All 12 of these areas were deemed to be of special interest or potential importance to the overall population of the Hawaiian green turtle. Other sites of significance are known to exist in the main Hawaiian Islands, notably the Na Pali Coast of Kauai, and Punaluu, Kaalualu, and Kiholo on the Island of Hawaii. However, except for the studies previously mentioned (Balazs 1976, 1980b, 1982), more comprehensive investigations must await the availability of sufficient resources.

Underwater Surveys

Underwater surveys with scuba and by skin diving were made to examine key foraging and resting places and to gather relevant ecological data. A 4.5 m Zodiac with an outboard motor was used in this work as needed. The Zodiac that was available for work on Maui and at Keomuku, Lanai was equipped with an electronic depth finder.

Two or three divers working within visual range of one another systematically covered as much underwater habitat as possible within the allotted time. With the exception of Kahului Bay where brief skin diving occurred at night, all diving surveys took place during the daytime. The use of scuba to search for turtles at night in resting habitat would undoubtedly have resulted in greater numbers being located at certain sites. Turtles are less apt to flee from an approaching diver at night. In addition, the use of underwater dive lights can temporarily blind or disorient turtles making them easier to capture. Nevertheless, the nighttime use of scuba was not considered feasible or safe for most of the study sites examined.

Terrestrial Surveys

Terrestrial surveys were conducted along coastlines to observe foraging turtles and characteristics of the nearshore and intertidal habitat. Observations were often carried out during morning twilight, a known active feeding period for the Hawaiian green turtle. At Kahului Bay, turtles attracted for thermoregulation to the warmwater discharge from a power plant were censused from shore as they periodically surfaced to breathe.

Capture Efforts

Turtles were sampled alive and unharmed by means of (1) large-mesh tangle nets, (2) a bullpen net, and (3) scuba and skin diving to facilitate capture by hand. All three of these methods have been successfully employed to study and tag green turtles in coastal waters of the Hawaiian Islands.

Large-mesh tangle nets were used to catch turtles at Kawela Bay and Kahului Bay. These nets were constructed of 2-mm diameter nylon twine with a stretched diagonal mesh of 46 cm (23 cm^2 mesh) and depths ranging from 1.5 to 3.5 m. The length of the nets ranged from 20 to 60 m. The nets were set at the surface extending vertically through the water column. They were deployed close to shore (<100 m) using a large inner tube with a plywood bottom. The nets were checked from land with binoculars and a spotlight (at night) every 20-30 min to see if turtles had been caught. Entangled turtles were removed from the net as soon as possible and brought to shore in the inner tube.

A large bullpen net owned by a commercial fisherman was used to sample turtles at Palaau. This method of fishing was introduced to Molokai several decades ago from the Philippines where it is called "baklad." At present only two bullpens are known to be in use in the Hawaiian Islands. Both are on Molokai where the wide shallow reef flat along the southern shore makes their use feasible.

The bullpen consisted of four pieces of net set from a specially designed 6.5 m boat. The pieces were deployed in a manner to block off and divert turtles (and fish) swimming along the reef flat into an enclosure where they were unable to escape. One section of net 250 m long served as a guide, set perpendicular to shore, that prevented the turtles from moving parallel to the shoreline. When this barrier was encountered, the turtles turned seaward and followed the guide into another section of net 200 m long set in a circle. Two other 100 m pieces of net were each positioned at 45° angles to the guide at the point where it fed into the circular enclosure. These wing nets created a funneling effect to help lead the turtles into the enclosure and prevent escape once inside. The nylon webbing used in the four pieces of net had a stretched mesh of 5-7 cm. The depth of each net was 4 m, but they were set in water ranging from only 0.5 to 3 m deep. Once captured, turtles were removed from the enclosure by grabbing them as they hit the net trying to escape, and by seining the enclosure during the course of landing the commercially sought fish.

The tagging of turtles caught incidentally during bullpen netting on Molokai is an ongoing activity in cooperation with commercial fisherman Edward Medeiros and State of Hawaii Aquatic Biologist William Puleloa.

Tagging and Biometrics

Turtles were tagged for long-term identification with numbered and addressed Inconel[1] alloy tags, size 681, custom made by the National Band and Tag Company of Newport, Kentucky. Balazs (1980b, 1982, 1983) described the history of these tags used in Hawaii and their superior corrosion resistance in contrast to ones made of Monel alloy. The tags measure 25 x 9 x 8 mm, weigh 3.5 g, and are self-piercing and self-locking. The manufacturer's applicator was modified slightly to lessen damage to tissue around the tagging site (Balazs and Gilmartin 1985). Depending on the turtle's size, from one to three tags were applied to offset tag loss. Tagging sites were the trailing edges of the front flippers and, when appropriate, along the inside trailing edge of a hind flipper well under the carapace.

Biometrics recorded on each turtle consisted of: straight-line and curved carapace length from the center of the precentral scute to the posterior tip of a postcentral scute; straight-line carapace length from the center of the precentral to the notch between the postcentrals; straight-line and curved carapace width at the widest point (the sixth marginal scute); straight-line plastron length along the midline; straight-line head width at the widest point; tail length from the posterior rigid edge of the plastron to the tip of the tail; and straight-line flipper width from the claw scale to the sixth scale on the trailing edge. Body weight was also recorded on a small number of turtles.

The straight-line carapace length taken to the posterior tip of a postcentral scute is the standard measurement used throughout this report, unless otherwise stated.

Food Sources and Epizoites

Food sources were determined by sampling the turtles' stomachs with a plastic tube inserted through the esophagus. Water was introduced at low pressure with a garden hose or enema bag to gently flush out food particles. In addition, unswallowed particles of food were removed from the mouth for identification. Field techniques for sampling dietary contents in turtles are discussed in detail in Balazs (1980a) and Legler (1977). Observations made of turtles feeding at specific sites also permitted the direct collection of forage during underwater surveys.

Food items were preserved in dilute Formalin and identified to the lowest taxon possible. Frozen bulk samples collected from foraging habitat in Kahului Bay were biochemically analyzed to determine major nutrients and mineral composition.

Epizoites found on the skin and hard surfaces of turtles were sampled, preserved in dilute Formalin, and identified to the lowest taxon possible.

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[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Deep-Body Temperatures

A telethermometer manufactured by Yellow Springs Instrument Company (Model 46 TUC) equipped with a thermistor probe (No. 401) was used to measure the deep-body temperatures of several turtles at Kawela Bay and Kahului Bay. The probe was inserted through the cloaca until its tip was estimated to lie within the large intestine. This method is identical to the one followed by Whittow and Balazs (1982). Temperatures were recorded immediately after the turtles were captured and brought to shore.

Blood Sampling and Bone Biopsies

Blood sampling followed the methods described by Bently and Dunbar-Cooper (1980) and Owens and Ruiz (1980). A needle and vacuum collection tube were used to draw blood from the paravertebral sinus on either side of the midline of the dorsal neck surface. Serum samples from immature turtles were frozen for future analysis of testosterone levels to determine sex. Whole blood samples were frozen for future analysis of genetic information using specific enzyme stains on isoelectrofocused gels.

Electro-Immobilization

The physical movement of the turtles was effectively controlled on land while collecting data by using a portable electro-immobilizer, Feenix Stockstill Mark I (Feenix International Ltd., Lake Wylie, South Carolina). Electro-leads were clipped to the inguinal region of a hind flipper and to the axial portion of a front flipper on the opposite side. Metal tags applied first at these sites provided ideal contact points to attach the leads. Immobilization and the turtle's recovery of normal movements were immediate when the unit was turned on and off. Immobilization results from minute electrical pulses which affect the nervous system causing skeletal muscles to contract and pain to be blocked out. A similar device called TENS (Transcutaneous Electrical Nerve Stimulation) is used on humans to relieve chronic pain and replace injectable anesthetics. The Feenix Stockstill unit is powered by a 6-V alkaline dry cell battery giving a maximum current of 240 mA at 55 V. A setting of 60-120 mA would usually eliminate all struggling, but still allow normal respiration and movement of the turtle's head and neck. The unit is manufactured for use on large domestic livestock, but was tested successfully by Wood and Wood (1983) as a method of surgical anesthesia for captive green turtles. The present study appears to be the first in which the unit has been routinely used to restrain wild-captured turtles to facilitate data collection and lessen injury to the researcher and the turtle.

FINDINGS AT PRINCIPAL STUDY SITES

Kawela Bay, Oahu

Physiography

Kawela is a small shallow bay covering approximately 20 ha (50 acres) located at lat. 21°24'N, long. 158°01'W on Oahu's northwest shore (Fig. 3). It is the only naturally sheltered body of water on this exposed windward coastline. A fine-grained calcareous sand beach extends for about 900 m along the bay's innermost shore. In contrast, the seaward edges on each side of the bay consist of elevated limestone rock 1-2 m in height. The maximum depth in the bay is only 3 m at high tide. However, at low tide the east and west margins are <0.5 m deep, and some bottom areas become fully exposed. The reef bottom of the bay is a mixture of limestone outcroppings and boulders, fine sand and silt, coral rubble, and live corals. Aecos (1981), Oceanit Laboratories (1985), and Clark (1977) provide further information on many aspects of the submerged and terrestrial characteristics of the bay.

A significant feature of Kawela Bay is the presence of a freshwater spring and pond (Punaula Pond) near the west shore (Taylor 1936). Fresh water percolates through the ground into the bay along this shoreline and possibly elsewhere. Fresh water also discharges at several point sources within the bay just a short distance from shore. Groundwater of this nature may provide elevated levels of certain nutrients that are beneficial to algal growth (Johannes 1980).

The entire shoreline of Kawela presently consists of small rural dwellings interspersed with ironwood trees (Casuarina sp.) and coconut palms. Very little illumination originates from these houses at night. However, the eastern half of the bay is scheduled for major resort development in the near future. Similar plans exist for the adjacent coastline extending from Kawela to the large hotel (Turtle Bay Hilton) which now exists about 3 km to the northeast on Kuilima Point (Yoneyama 1985). The exposed coastal indentation immediately to the northeast of Kawela Bay is known as "Turtle Bay." This place-name appears to be of relatively recent origin and apparently not of historical Hawaiian derivation (Coulter 1935; Pukui et al. 1976).

Ecological Aspects of the Turtles Captured

Netting efforts at Kawela Bay resulted in 36 captures (Tables 1,2). One turtle was recaptured once and another recaptured twice during subsequent netting efforts. In addition, a single turtle was caught by hand during scuba surveys in deep water immediately outside of the bay. Thirty-four individuals were therefore examined and tagged at this location. When netting was conducted for two consecutive days and nights (26-28 March 1985), no repeat captures resulted. Several other turtles are known to have become briefly entangled in the net, but they escaped before it was possible to retrieve them.

All of the turtles were caught on the west side of the bay at a location where sufficient water depth and bottom substrate made it possible to safely and properly set the large-mesh tangle nets.

All of the turtles were caught at night when they came into the bay to feed or, in a few cases, within 2 h after sunrise or just before sunset. On the second sampling visit undertaken on 8-9 April 1985, a short section of net was set on the bay's east side. Shallow water conditions, combined with numerous limestone outcropping in the area, caused this attempt to be abandoned without turtles being captured. Further netting was therefore confined to the west side where conditions were amenable to the sampling procedure.

The catch rates (netting efficiency) at Kawela were high, as was expected based on prior interviews with residents and first-hand sightings of turtles from shore. Overall, only 108 meter-hours (m-h) of netting effort was expended for each turtle captured (Table 2). The numbers and kinds of biological samples collected from turtles at Kawela, as well as the other study areas examined, are shown in Table 3.

Partitioning of the 34 turtles into 10-cm size classes by straight carapace length (Tables 4, 5) gave the following population structure: 35-45 cm = 21%; 45-55 cm = 21%; 55-65 cm = 21%; 65-75 cm = 35%; and 75-85 cm = 3%. The largest turtle captured at Kawela was 75.1 cm, therefore none were of an adult size (>82 cm). Comprehensive body measurements, along with the identification numbers of the flipper tags used, also appear in Tables 4 and 5. The carapace lengths and body weights for a random sample of six turtles are given in Table 6.

Taxonomic identification of the stomach contents sampled from 12 turtles at Kawela revealed that the red alga, Acanthophora spicifera, is a prominent source of food (Table 7). Ten of the 12 samples (83%) consisted of 99% or more A. spicifera. It is significant to note that this alga was accidentally introduced into Hawaiian waters, probably from the western Pacific on the bottom of a barge in 1950 (Doty 1961). Acanthophora is now known to occur on at least six of the main Hawaiian Islands (Oahu, Kauai, Molokai, Lanai, Maui, Hawaii). MaGruder and Hunt (1979) state that its introduction "...has displaced many of the algal species previously inhabiting Hawaiian reef flats." However, this conjecture is not supported by comprehensive studies conducted by Russell (1981).

Algae prominent in the stomach samples from the two other turtles shown in Table 7 included Amansia glomerata and Codium edule (from tag No. 8489) and Laurencia mariannensis (from tag No. 8493). This is the first record of L. mariannensis being eaten by a green turtle in the Hawaiian Islands.

An analysis of the complete stomach contents removed from a 55.5 cm turtle that died at Kawela Bay on 28 March 1985 revealed mostly Ulva reticulata and Pterocladia capillacea (Table 8). Fourteen other species of algae were also identified in trace or very small quantities. In addition, the small black colloidal sponge, Chondrosia chucalla, was present in low numbers.

Algae regularly found growing on the skin and hard surfaces of the turtles caught at Kawela were identified as Sphacelaria tribuloides and Polysiphonia tsudana (Table 9). Melobesia, an encrusting red alga, also commonly occurred on the carapace of some of the turtles. In addition, the small and harmless skin barnacle, Platylepas hexastylos, was frequently seen on the neck and pelvic area.

Six of the 34 turtles captured (18%) displayed some evidence of external injury or abnormality (Table 10). Two of these (tag No. 8505 and 8809) were suggestive of previous shark attack. Another appeared to involve the early growth stages of tumors (fibropapillomas) associated with the eyes. Balazs (1986a) gives an overview of the increasing incidence of tumors in Hawaiian green turtles. Another abnormality noted at Kawela was the passage through the gut of synthetic fishing line (Table 10). It is not uncommon for sea turtles to ingest plastic debris of this nature. In some cases, serious adverse effects such as intestinal blockage can result (Balazs 1985c). However, in the present incident the line was eliminated with no apparent difficulty.

The turtle found dead in Kawela Bay on the morning of 28 March 1985 was apparently too weak to rise to the surface to breathe after being caught in the net. The turtle was comatose on the bottom at low tide in water <0.5 m deep. Attempts to revive it were unsuccessful, although initially there were some encouraging signs of life in response to artificial ventilation of the lungs (Balazs 1986b). Freshly preserved tissue from the lungs, liver, intestines, and kidney were histologically examined by a pathologist. This analysis (Table 11) suggested that debilitation of the turtle had resulted from cardiovascular fluke infection (Digenea: Spirochidae). The most extensive tissue damage was found in the lungs and small intestine. The extent of such infection in Hawaiian turtles, and the intermediate host involved in transmission (presumably an item in the turtles' diet), remain unknown. Severe cases of parasitism by flukes have been documented in certain other sea turtle populations (Wolke and Brooks 1982; Rand and Wiles 1985).

The two turtles recaptured at Kawela on 3 July 1985 (measuring 64.0 and 54.4 cm) exhibited a mean growth rate of 0.11 cm per month after having been tagged here 3 months earlier (Table 12). At this rate, a 35 cm juvenile establishing residency at Kawela from pelagic habitat could require 36 years to reach the minimum adult size of 82 cm.

The deep-body temperatures of the turtles recorded at Kawela decreased with the approach of low tide and the concomitant increased influence of cold water from the spring (Table 13). The ambient ocean temperatures in this same area at high tide during late June and early July ranged from 26.5° to 27°C. At low tide, between 0530 and 0700, the ambient temperatures were 23°-24°C. The cooling effect on the turtles was therefore directly related to the tidal stage and the length of time the turtles spent foraging in the area before capture. Body size would also be a factor, since smaller turtles would be expected to cool faster. The lowest deep-body temperature of a turtle recorded at Kawela was 24.8°C, and the highest was 26.7°C (Table 13).

Foraging Habitat Appraisal

Surveys accomplished from shore and underwater in conjunction with the netting demonstrated that significant foraging habitat at Kawela occurs primarily along the east and west sides of the bay. Benthic algae prominent in these relatively shallow areas consist of A. spicifera and U. reticulata. The former occurs on hard bottom substrate, including coral rubble, and the latter is typically found here growing in the Acanthopora, tangled within its branches. Amansia and Pterocladia also occur in the high density foraging zones along each side of the bay. However, these algae are much less abundant, and the latter is mainly confined to limestone rocks that are partially exposed at the lower tides. A small bivalve mollusk, Isognomon californicum, also grows on some of these rocks, but was not found among the stomach contents examined. Numerous other species of algae occur in the bay, as reflected in part by Tables 7 and 8. However, they only account for minor dietary components, in contrast to the major ones previously mentioned. Nevertheless, these algae may possibly play an important role in supplying certain essential trace nutrients that are deficient in the other species. A number of other algae were present in the bay, such as Dictyota bartayresii, and U. fasciata, but were absent in the stomach contents examined. On several occasions, drifts of algae were blown or washed ashore along the inner sand beach, especially at the east and west corners of the bay. Some of this drift material, notably Sargassum polyphyllum and Turbinaria ornata, was derived principally from areas outside of the bay. Fecal pellets from the turtles were also found washed ashore.

The frequency of turtles sighted from shore was consistent with the temporal foraging pattern ascertained from net captures. That is, when it was deep enough, turtles entered the bay at evening twilight or during the nighttime and remained active usually until shortly after sunrise. The greatest activity was consistently seen at morning twilight, although this is somewhat biased because turtles surfacing to breathe were usually not visible at night except when a bright moon existed. The greatest numbers seen from shore were on the mornings of 18 October and 20 November 1985 (Table 1) when an estimated 15-20 turtles were present at one time on the bay's east side. Some were within only 3 m of the sand beach and were likely feeding on detached particles of algae accumulated along this zone. No turtles were ever seen in the bay during the middle of the day, either from shore or during diving surveys.

During the early morning periods of foraging, few turtles were seen using the central section of the bay. When turtles were observed here, they appeared to be leaving the bay, possibly taking advantage of the deeper sand channel located in this area. The prostrate green alga, Codium arabicum, occurs on hard substrate in this deeper central region of the bay. This species (along with C. edule) is highly favored as a food source by green turtles at certain other coastal pastures in Hawaii. At Kawela the use of Codium appears to be minor, based on the stomach samples obtained.

All observational surveys at Kawela listed in Table 1 included periods of time spent looking for turtles foraging in nearshore waters at the adjacent southern end of Turtle Bay. None were sighted along here, except for a single 45-55 cm juvenile seen 18 October 1985 surfacing for a brief time 20-30 m from shore. Algae used as food, such as the ones seen in abundance in Kawela Bay, were not found in Turtle Bay during shoreline and diving surveys. Furthermore, unlike Kawela Bay, information gathered during interviews with local residents indicated that Turtle Bay was not an area where turtles had been fished during past years. However, turtles have been occasionally caught and killed in gill nets set for fish and lobster in Turtle Bay. During past years this is said to have been a somewhat common source of mortality for turtles at Kawela Bay.

The northern portion of Turtle Bay in the vicinity of the existing hotel was not included in the present study. Some turtles are reportedly sighted there, but not in abundance.

Resting Habitat Appraisal

Hawaiian green turtles residing in benthic habitats appear to spend most of their time alternating between periods of active foraging and quiescence. The rest periods are spent on the bottom, usually in small shelter caves or near protective outcroppings that are often associated with submarine cliffs. At Hawaiian coastal areas examined during previous studies, resting habitat has been found in proximity to the foraging site, usually within only 2 km or less of each other. An underwater bench exists around much of the coastline of the main Hawaiian Islands, beyond which great depths occur very rapidly. This discrete drop-off usually defines the 18-27 m (10-15 fathom) depth curve, and it is here where turtles often go to rest.

Other habitats utilized for resting consist of vertical holes and crevices (known locally as "potholes") and vertical-walled channels within the reef flat. These sites are closer to shore and normally are not deeper than 8 m. Smaller turtles in particular are apparently able to find sufficient shelter at these sites, even when large waves and strong currents exist. The larger turtles, however, show a preference for resting in the deeper water along the drop-off. Because they are shallower, resting areas within the reef flat are more liable to intrusion by humans, hence the greater likelihood of turtles being disturbed, displaced, and successfully hunted. Scuba gear is almost always necessary for direct human intrusion into resting habitat along the drop-off.

A common feature of resting habitat in Hawaii is fine-grained sand or powdery silt at the site where the turtles settle to rest. The size of these soft sandy sites can vary considerably, ranging from a small accumulation no larger than the turtle itself, to the broad expanse sometimes present along the base of a drop-off.

During periods of rest, turtles can stay submerged for long periods before coming up to breathe. Adult turtles at French Frigate Shoals equipped with small radio transmitters were found to have bottom times of up to 2-1/2 h (Dizon and Balazs 1982 and unpublished data).

Surveys at Kawela indicated that turtles do not normally use the bay for resting purposes, even though it is reasonably well sheltered against large northerly winter surf and prevailing onshore winds. The bay is used almost exclusively as a foraging pasture, with turtles resident to the area commuting to resting areas in nearby habitat. It is unclear why turtles do not rest within Kawela Bay. Possible factors might be an insufficient depth, the absence of significant bottom relief, and an excessive level of human intrusion (i.e., boating, water recreation, fishing activities) for such a small body of water.

Visual searches using a Zodiac in combination with scuba surveys made during two study visits (14 and 25 June 1985) found turtles at a drop-off 800-900 m directly outside of the bay. Along here the relatively featureless sea floor abruptly changes from about 8 to 24 m deep. Four turtles were observed floating at the surface, and three were seen underwater. Tracking the drop-off in a westerly direction did not result in additional sightings. However, when it was followed to the east, the cliff curved toward shore into Turtle Bay, where it became less pronounced and much shallower (11-14 m). Just before entering Turtle Bay during the scuba survey, a 42.5 cm turtle was hand captured after it was seen resting on a ledge 12 m deep. Five turtles were spotted at the surface inside Turtle Bay, but only one was seen while searching underwater. The poor visibility due to fine suspended particles may have been responsible for this low count. Under turbid conditions turtles can apparently see or hear an approaching scuba diver and often flee long before coming into the diver's field of vision.

Fewer turtles were encountered in typical offshore resting habitat than might be expected, considering the number captured and consistently sighted inside of Kawela Bay. The limited available time spent scuba diving (7.5 man-hours, Table 1) undoubtedly contributed to these findings. Nevertheless, some general conclusions are possible based on the existing information. During all times of the year, turtles that forage within Kawela are likely to rest in deeper water and shelter found along the drop-off. However, when large northerly surf subsides during the summer months, calmer conditions in Turtle Bay make it possible for turtles to rest there. Since the turtles are known to feed at night, resting must mainly occur during the daytime. However, since individual turtles are not likely to forage on consecutive nights, they must sometimes rest at night, especially during nocturnal low tides.

Palaau, Molokai

Physiography

Palaau is a relatively remote and uninhabited coastal area of Molokai, located at approximately lat. 21°06'N, long. 157°07'W along the central portion of the island's southern shore (Fig. 4). A large but very shallow fringing reef borders the entire region extending seaward for a distance of 1.0 to 1.5 km. Beyond the outer reef edge, where breakers occur, the bottom descends rapidly into the Kalohi Channel separating Molokai from

Lanai by only 20 km. Within 500 m of shore the bottom at Palaau consists of soft mud, calcareous rock and rubble with many areas exposed at low tide. Farther out the depths rarely exceed 3 m and the bottom turns into a composite of coral gravel and fine terrigenous silt interspersed with live coral heads. The sedimentation from coastal soil runoff dominates all areas of the Palaau reef flat. The incoming tide and wind-driven waves quickly stir up the bottom producing murky conditions with little or no visibility, except along the seaward edge of the reef.

A very narrow and unmarked channel 4 m deep leads from the open ocean through the breakers into the Palaau reef flat. A wooden shack built on pilings several decades ago is located close to shore in the channel area. At one time turtles were held alive in pens under this shack before being butchered.

Thick stands of the red mangrove, Rhizophora mangle, cover much of the Palaau shoreline and intertidal reef flat. This species was intentionally introduced to the Hawaiian Islands from Florida in 1902. It was initially planted on Molokai in an attempt to retain soil along the island's eroded southern slopes (Wester 1981). Due to encroachment by mangroves, many of the abandoned ancient Hawaiian fishponds along this shore, including the ones at Palaau, have rapidly deteriorated (Summers 1964, 1971).

Behind the mangroves and along other sections of the Palaau shoreline the arid terrain consists mainly of thorny kiawe trees, Prosopus sp., and salt flats covered with pickleweed, Batis maritima. The land here is used primarily for cattle ranching. However, inland there is also an agricultural plot planted in corn, and an experimental shrimp farm using seawater pumped up into ponds from a well.

Human intrusion into the Palaau reef flat is constrained by a number of factors, including dense shoreline mangroves, a dangerous ocean channel, an unimproved road sometimes requiring a four-wheel drive vehicle, and silt-laden water conditions that are unappealing to most divers. Nevertheless, relatively easy access is possible from the Kaunakakai pier and harbor located just 8 km to the east of Palaau (Fig. 4). From here, a small boat with a shallow draft can be motored directly over the reef flat inside the breakers at high tide. The use of gill nets at Palaau commonly occurs by this route in what appears to be a very productive area for fin fish. Wester (1981) noted the importance of mangrove swamps as nursery grounds for fish and crustaceans. The effects of established mangrove areas on the marine ecosystem and fisheries in Hawaii, such as at Palaau, are in need of further investigation.

Ecological Aspects of the Turtles Captured

Bullpen netting at six separate sites at Palaau over 4 days in April and 4 days in July 1985 resulted in 135 captures (Tables 1 and 14; Fig. 4). Six turtles were captured twice during this period, and five others were recoveries of turtles tagged earlier at Palaau during an ongoing cooperative project with the same commercial fisherman. In addition, four turtles were caught by hand while skin diving. One hundred and thirty-three individual turtles were therefore examined at this study area.

When the net was left at the same site for two consecutive days and nights on two separate occasions (Fig. 4, site B, 23-25 March; and site E, 16-18 June), only a single turtle was recaptured from the previous day's fishing. The catch rates, however, dropped on the second day on both occasions, from 470 to 750 m-h per turtle, and from 500 to 1,050 m-h per turtle (Table 14). Overall, 680 m-h of netting effort was expended for each turtle captured at Palaau. This rate is considerably higher than that at Kawela Bay (108 m-h per turtle). However, the two netting techniques may not be entirely comparable. In the case of the bullpen, turtles herd themselves into an enclosure, whereas with tangle nets they become snarled in the net itself. It is not known if one method is more efficient than the other. Under certain conditions, some turtles are capable of evading or escaping from both kinds of net. At present it is not feasible to do a comparative study of the two netting techniques, since the use of large-mesh tangle nets at Palaau is impeded by fouling from sharks and rays.

Each of the six netting sites (A through F shown in Fig. 4) were situated in a line along the Palaau reef flat separated by distances of 700-1,000 m. The greatest number of turtles caught in a single overnight fishing cycle (usually 18-21 h) was 39 at site F. The fewest captured (3) was at site C, probably because the net was farther from shore at this location and set in deeper water (3 m). At the other fishing sites, the circular enclosure of the net was usually in water not more than waist deep (1 m or less).

All personnel vacated the netting site until the following morning once the pieces of net had been set out properly. Deployment usually required 1-2 h. It was not possible to watch the net continuously to determine when turtles were entering it. The net was located too far from shore, covered too large an area, and the water was usually too cloudy to make observations. At Palaau, unlike Kawela Bay, some turtles were sighted foraging in the daytime close to shore (<500 m) during periods of incoming high tides. Captures in the bullpen, therefore, likely occurred diurnally, as well as at night when most of the turtles (and fish) are believed to enter the shallows to feed during a rising tide.

Partitioning of the 133 turtles by 10 cm size classes gave the following population structure: 35-45 cm = 21%; 45-55 cm = 29%; 55-65 cm = 27%; 65-75 cm = 19%, and 75-85 cm = 5%. The largest turtle captured in this study area was 79.4 cm. Although now relatively rare, larger turtles have been captured at other times during bullpen netting at Palaau. For example, on 10 May 1984 two turtles found in the enclosure by the commercial fisherman were reported to be "too large" to handle and tag. Instead, they were released by lifting up a section of the net. In the past, 25 or more years ago, it was reportedly not unusual for turtles >90 cm and >125 kg to be caught by bullpen net at Palaau.

Comprehensive body measurements, including the identification numbers of the flipper tags used at Palaau, appear in Tables 15 and 16. The linear relationship of the straight and curved carapace length for a composite of 163 turtles sampled from Palaau and Kawela Bay is illustrated in Figure 5.

It has been suggested that the ratio of the curved and straight width of the carapace may serve as a useful index of body thickness in green turtles (Balazs 1980b). The carapace in certain populations, including Hawaii, appears to have a more domed shape, hence a thicker or deeper body. However, accurate comparisons have not been carried out. In the index method proposed, a higher ratio would indicate a proportionately thicker body. Figure 6 displays the relationship of straight carapace length and the ratio of the curved and straight width for 162 turtles from Palaau and Kawela Bay. It is apparent that the ratio does not remain constant, but rather becomes greater as carapace length increases. Turtles larger than about 65 cm appear more likely to have a proportionately thicker body.

Two techniques were used in this study to measure straight carapace length. As mentioned earlier, the standard method was taken from the precentral scute to the posterior tip of a postcentral scute. The second method, recorded for comparison, was taken from the precentral scute to the V-shaped notch formed where the two postcentral scutes join. This latter method alone has sometimes been used by other researchers, so it is worthwhile to know the relationship of the two measurements. Figure 7 provides such an illustration, with the "notch" length expressed on the Y-axis as a percentage of the standard length. Some turtles in the smallest available size class (35-45 cm) show greater variability than larger turtles (>45 cm). This can be attributed to the more highly serrated postcentral and marginal scutes that are often present on small Hawaiian green turtles newly recruited from pelagic habitat. These serrations seem to diminish rapidly with residency in benthic habitats. Changes in carapace growth, as well as abrasion from physical contact with coastal substrate, are undoubtedly responsible. It is suggested from these data (Fig. 7) and other field observations that a turtle under 45 cm with a notch length that is <99% of its standard length is likely to be a very new arrival to benthic habitat.

A composite of 20 turtles from Palaau and Kawela Bay that were weighed (Table 6) are illustrated in Figure 8 as a function of their carapace length.

The identification of stomach contents collected from 21 turtles at Palaau ranging in size from 39 to 71 cm revealed that Acanthophora spicifera was again the dominant food source (Table 17). This alga was found in 13 of the turtles (62%), and comprised from 20 to 99% of each sample volume. In five of the turtles, it made up 90% or more of the sample. All size classes were represented among the turtles that fed on Acanthophora. Furthermore, no preferences for any of the other food sources were evident based on size.

Amansia glomerata and Spyridia filamentosa (also red algae) were identified as food items next in order of prominence after Acanthophora. Each of these food items was found in 6 (29%) of the 21 turtles comprising sample volumes of 15% or greater. Three turtles that had been feeding on

Amansia, and five that had been feeding on Spyridia, had also eaten Acanthophora. However, Amansia and Spyridia were not found together in any of the stomach samples.

Other noteworthy algae include: Hypnea cervicornis and H. nidifica - four turtles with sample volumes of 10-50%; Laurencia nidifica - one turtle comprising 20% of the sample volume; Turbinaria ornata - one turtle comprising 40% of the sample volume; and Chondrococcus hornemanni - two turtles comprising 30 and 90% of the sample volumes (Table 17). This latter species is of special interest because of certain toxic compounds it is believed to contain. In previous studies Chrondrococcus has only rarely been found as a food item of the green turtle, and then only as a trace component.

Three (14%) of the 21 turtles sampled had been feeding on Halophila hawaiiana (sample volumes of 2, 50, and 75%). Halophila is the only seagrass (marine angiosperm) that occurs in the Hawaiian Islands. It has small oval blades, 1-3 cm long, and usually grows in low density meadows in shallow protected waters. In many other green turtle populations, seagrasses (i.e., Thalassia testudium) instead of algae form the major constituent of the turtle's herbivorous diet (Hirth 1971; Mortimer 1981; Bjorndal 1985).

The amphipod Hyachelia tortugae was found alive in 8 (38%) of the 21 stomach samples (Table 17). This highly specialized crustacean resides in the turtle's buccal cavity where it feeds on food residue. It was first described from green turtles in the Galapagos Islands (Barnard 1967). The amphipods obtained at Palaau were apparently dislodged and flushed out during the stomach sampling procedure.

Algae were commonly found growing on the external surfaces of turtles at Palaau (Table 9). In addition, skin barnacles, Platylepas hexastylos, and patches of encrusting Melobsia were commonly seen. Melobsia was also growing on the metal tags of recaptured turtles. In one instance, this alga was present in small patches after an interval of only 8 days in the wild (tag No. 8847).

Fifteen of the 133 turtles examined (11%) showed evidence of injury or other abnormality (Table 18). At least six of these (4.5%) were believed to have resulted from shark attack, and two others (1.5%) had puncture wounds almost certainly caused by spear or harpoon. Large tiger sharks are known to transit the Palaau reef flat, undoubtedly in part to prey on turtles. In recent years two such sharks >3 m have been caught in the bullpen enclosure, but an examination of their stomach contents was not possible. It should be noted that tiger sharks of this size are able to swallow whole turtles of up to at least 50 cm (20 kg). The dentition of the tiger shark allows larger turtles to be cut up for ingestion by a very effective sawing mechanism involving both of the shark's jaws.

None of the 133 turtles captured had fibropapillomas. However, on 16 October 1985 a 78-cm turtle tagged at Palaau by William Puleloa was reported to be severely afflicted with these growths. This is the first such case to be documented for the Island of Molokai.

Seven tagged turtles recaptured at Palaau after intervals of 3-32 months provided information on rates of growth (Table 19). The mean growth rate was 0.15 cm per month or 27 years to reach adult size. This is about 25% faster than the growth estimate obtained at Kawela Bay. More data are needed at both sites to determine if Palaau is indeed a better foraging pasture than Kawela in this respect.

Table 20 provides information on the homing behavior and site fidelity of 10 turtles captured at Palaau that were either released there or at other locations along Molokai's south shore. During past cooperative work with the commercial fisherman, the release of turtles elsewhere has sometimes been necessary because tide and weather conditions prevented staying at Palaau long enough to do the tagging and measuring. All turtles were released the same day they were captured. Two turtles released 8 km away at the Kaunakakai pier were recaptured back at Palaau after only 10 and 15 days. Another turtle that was released at Kawela (Molokai), 17 km to the east of Palaau, was recaptured at Palaau 15 months later. Six other turtles listed in Table 20 were recaptured at Palaau after having been caught and released there 3 to 32 months earlier. The apparent movement of one turtle away from Palaau was also documented. A 58-cm animal (tag No. 8634) originally tagged on 24 April 1985 was reported caught in a fisherman's net at Kawela (Molokai) 2 months later. The turtle was released there in good condition.

Foraging Habitat Appraisal

Significant foraging habitat for turtles was found all along the Palaau coastline in shallow nearshore waters where the identified major food sources of *Acanthophora* and *Spyridia* are consistently present in abundance. *Hypnea*, which seems to be a less preferred dietary item, also occurs here in abundance. All of these algae grow on hard-bottom surfaces and coral rubble heavily fouled with silt and interspersed with soft mud. The extreme turbidity of this nearshore foraging zone, which extends for up to 500 m from land, makes visual observations of the habitat nearly impossible. The only exception is during periods of low tide when portions of the substrate and marine vegetation are left exposed.

Other algae that are prominent in this area, and dependent upon hard bottom for attachment, include *Laurencia nidifica*, *Sargassum polyphyllum*, *Dictyota* spp., and *Lyngbya majucula*. In addition, the extensive mud flats within this shallow foraging zone commonly contain pastures of *Halophila hawaiiana*, as well as *Caulerpa sertularioides*, a green alga not found in any of the stomach samples. These two plants are held in place by a network of roots or rhizoids anchored in the mud. At many sites, *Halophila* has been able to retain and stabilize small mounds of sand and silt 1-3 m in diameter, thereby causing a denser meadow. In addition, the distribution of *Halophila* often extends seaward beyond the mud flats into depths of 1-1.5 m where live coral heads start to occur and the bottom changes into a mixture of coral gravel and silt. Turtles that forage on Halophila undoubtedly utilize this expanded area. However, Acanthophora, Spyridia, and Hypnea are almost totally absent here.

Amansia, which was equal in prominence to Spyridia in the stomach samples, was only infrequently encountered during diving surveys of the reef flat. This alga appears to be absent or rare in the nearshore foraging zone. Instead, limited quantities of Amansia grow farther from shore near the breakers in the shaded crevices of coral heads. Amansia may very well grow in greater abundance beyond the breakers, on the outer edge of the reef slope, where surveys were not conducted due to safety considerations. Asparagopsis taxiformis and Galaxaura rugosa are two highly visible algae that occur very commonly along the seaward region of the reef flat. However, neither species was identified from stomach samples, even in trace amounts, so they are presumably not eaten by the turtles. Asparagopsis (limu kohu), which is eaten by certain ethnic groups in the Hawaiian Islands, is known to contain mutagenic and likely carcinogenic compounds (Mower 1983).

During times of calm sunny weather and low tides, the shallow waters at Palaau heat up substantially from solar radiation. Temperatures recorded in the bullpen enclosure at 1 m depth during these warmer periods ranged from 28° to 29°C. Comprehensive thermal profiles were not undertaken, but in certain very shallow areas close to shore the water and underlying mud temperature was >31°C. The benthic algae and Halophila are apparently able to tolerate these extremes. Seawater temperatures averaged 25°-26°C at the net enclosure during normal trade-wind conditions.

Small seeps of brackish water can be seen at low tide along portions of the coastline, but not in sufficient volume to cool the nearshore waters. In the past century, before the deposition of silt from erosion, a large freshwater spring flowed into the sea at Palaau (Summers 1971). Kiawe trees may have also contributed to the drastic reduction of this spring. According to Apple and Kikuchi (1975), kiawe is a phreatophyte, that is, it robs moisture from the soil and may eliminate or reduce the flow of water from nearby springs. Kiawe was introducted to the Hawaiian Islands in 1828, and it has spread rapidly since 1900.

Recent work by Thayer et al. (1982) in the Caribbean indicates that green turtles, as herbivores, are likely to play a significant role in nutrient cycling by reducing the decomposition time of marine vegetation used as forage. This "short-circuiting" of the detritus cycle represents a potentially important beneficial link between the abundance of turtles in nearshore habitat and enrichment of the marine ecosystem. Considerable fecal material is undoubtedly released into shallow reef flats where turtles aggregate to feed, such as at Palaau and Kawela Bay on Oahu. The actual level and role of these fertilizers need to be determined.

Resting Habitat Appraisal

Diving surveys covering the Palaau reef flat (Table 1) determined that many turtles rest at the base of coral heads and in crevices, holes, and sand channels 2-5 m deep a short distance inside the breakers. Select bottom areas located here were completely sheltered from incoming waves and surge at all stages of the tide. Similar protection might also be expected during the winter months, since Palaau is not directly exposed to northerly surf.

The reef zone along the inside of the breakers consists of an extensive maze of coral heads awash at low tide. The deep holes and channels among these heads often have deposits of fine silt that quickly become suspended when disturbed by a diver or a turtle. In addition, recesses in the substrate are heavily shaded and difficult to view with bright sunlight contrasting from overhead. Access to these sites for survey work was therefore greatly hampered, especially during low tide when the turtles were most likely to be resting. It was usually impossible to navigate the Zodiac through the exposed coral heads. On numerous occasions turtles were seen at a distance surfacing to breathe directly over holes and channels thought to be used for resting purposes. However, when the site was reached by skin or scuba divers, the turtles would often be gone, or only sighted briefly as they rapidly swam away. On several occasions it was noted that movement by a single turtle fleeing from the bottom would serve as a signal to others to do the same. This was true even when the other turtles were behind adjacent coral heads and unable to see an approaching skindiver.

Although turtles lie motionless on the bottom while resting, their eyes are almost always open and alert. An exception is when they are positioned head first into a resting site, rather than sideways or with their head facing out. One of the turtles captured by hand was resting >1 m inside a narrow cave with only a single opening. When the scuba diver carefully worked his way into this small space, the turtle made no attempt to flee. Instead, it slowly retreated even farther into the limited available space. Once the diver grasped the turtle and moved it to the entrance of the shelter, it then tried to swim away with great force. Turtles resting entirely hidden in small recesses have been seen elsewhere in the Hawaiian Islands. The sheltered area will often only be slightly larger than the turtle, thereby affording good protection against large sharks and ocean surge. It should be noted that turtles were never seen "wedged" into or under the substrate while resting. By adjusting their lung volume, a neutral or slightly negative buoyancy can be maintained to facilitate resting motionless with only minimal contact to the hard substrate.

Some turtles were also found resting on the bottom by coral heads located closer to shore, but still well outside the mud flat zone at Palaau. The turtles here were generally smaller (<50 cm) than the ones closer to the breakers. Like all of the turtles encountered in resting habitat, upon being disturbed there was a distinct tendency to swim seaward toward deeper water. Turtles already close to the breakers when first sighted would, as could best be determined, also flee seaward using channels leading through the surf. It seems likely that resting habitat, especially for larger turtles (>65 cm), may also exist in deeper water on the outer slope beyond the Palaau reef flat.

Directly toward shore from netting site D (Fig. 4) a deep natural trench approximately 300 m long by 75 m wide occurs abruptly in the mud flat in front of the ruins of an ancient fishpond (Pakanaka Pond). Fishermen on Molokai have reported that turtles rest on the bottom at this location. The exact depth is unknown, but may range up to 7 m. An attempt to inspect the bottom with scuba and look for turtles was unsuccessful because of zero visibility in the silt-laden water. Two turtles were seen in this area surfacing momentarily to breathe, but they quickly dove again, probably in response to the presence of the survey boat and personnel.

Kahului Bay, Maui

Physiography

Kahului Bay is located at lat. 20°54'N, long. 156°28'W on Maui's northern windward coast adjacent to the island's major urban centers of Kahului and Wailuku (Fig. 9). Kahului Harbor is situated within this bay and is the only deep-draft harbor on Maui. Protection for vessels is afforded by two breakwaters 2,300 and 2,700 m long, with a 180-m wide entrance channel between them. Breakers occur on both sides of the channel and continue along the coast, especially to the east, for up to 1 km from shore.

Except for two sections of beach, the shoreline inside Kahului Harbor is made up entirely of artificial structures. Wharfs and other facilities, including a large Matson freight terminal, are located on the harbor's east side near the projection of land called Hobron Point. On the west side there is a cement boat ramp. A 40-MW generating station is situated next to the freight terminal outside the harbor boundaries on the seaward side of Hobron Point. In addition to numerous commercial, residential, and agricultural areas surrounding Kahului Harbor, there is also a nearby jet airport, a waterbird refuge (Kanaha Pond), and a sewage plant that disposes of treated effluent by injection into the limestone substratum. Armstrong (1983) and Clark (1980) provide further information on other aspects of Maui's coastal zone in the vicinity of Kahului Bay.

The principal study site for turtles in Kahului Bay was the nearshore waters of Hobron Point in the immediate vicinity of the warmwater outfall of the power plant. The station's cooling water system uses 55 million gallons per day of seawater pumped up from wells 60 m deep. The intake temperature of this water is 23°C, and the outfall temperature is reported to range from 27° to 33°C, depending upon the load (Hawaiian Electric Co. and Bishop Museum 1975). The four steam turbine generating units discharge their cooling water along a 50-m stretch of shoreline just outside the plant. Upon leaving the outfall ports, the heated water cascades a short distance down a boulder embankment and enters the sea with relatively little force. A clear plume of warm water is formed next to the embankment and retained there to some extent by onshore tradewinds. The clear plume contrasts sharply with adjacent water which is very turbid but nevertheless much warmer than farther offshore. The plume is usually about 20 m in diameter and varies in size and shape with wind and tidal conditions.

The power plant was built in 1947 in essentially the same configuration that it exists today. The gathering of a few turtles near the warmwater discharge at night has been known by some plant employees and other local residents for many years. Recently, however, the numbers are believed to have noticeably increased, possibly because fewer are now being killed there since legal protection was granted. Rene Sylva, a former turtle net fisherman first notified research personnel in April 1984 about this aggregation.

A security fence extends around the entire plant, but public access to the discharge area is made possible by a narrow footpath along the top of the 6 m high embankment just outside the fence. A wooden stairway leads down the embankment so that periodic samples of the cooling water can be safely taken by power plant personnel. The stairs and part of the discharge area are illuminated at night by a small floodlight that operates automatically at dusk and dawn. Some background illumination also originates from various security lighting at the power plant and the nearby freight terminal.

A small number of people regularly fish from the embankment at night with rod and reel whenever the onshore winds are not excessive. Other activities carried out here include recreational "turtle watching" during the evening hours, as well as concerted periodic attempts to take turtles, some of which are undoubtedly successful. Several local residents indicated that turtles are sometimes shot here with firearms as a means of capture.

Ecological Aspects of the Turtles Captured

Large-mesh tangle nets used on five nights (7 May and 17-20 June 1985) near the warmwater outfall in Kahului Bay resulted in eight captures (Tables 1 and 21). Overall, 117 m-h of netting effort was expended for each turtle captured. One turtle was caught twice during this time, and two others were captured by hand while skin diving right next to the embankment. A total of nine turtles were therefore examined, measured and tagged at this site (Table 22).

Relatively few turtles were captured in the nets despite the large numbers consistently seen from shore aggregated around the small area of the outfall. The nets were almost certainly being detected and actively avoided by the turtles, even though they were set in turbid shallow water just outside the clear plume formed by the discharge. The turtles were often seen surfacing to breathe alongside the net, thereby giving the impression that they were swimming around, or in some places, possibly under it to reach the warmer water. On several occasions a turtle would become entangled for only a few minutes, during which time there would be bursts of violent splashing before it escaped. When a turtle that was securely caught in the net had to be removed and brought to shore in the inner tube, the subsequent sightings of turtles would decline dramatically for the rest of the night. The departure of most turtles from the area whenever personnel entered the water greatly limited the amount of work that could be accomplished nightly. No turtles were ever seen in the vicinity of the outfall during the daytime, either from shore or during diving surveys, nor were any such reports received during interviews with power plant personnel or other local residents.

The size composition of the nine turtles was: 35-45 cm = 11%; 45-55 cm = 0; 55-65 cm = 0; 65-75 cm = 11%; 75-85 cm = 22%, and >85 cm = 56%. On the basis of tail size (Table 22), it was possible to determine that two of the turtles captured were males (29%) and five others were females (71%). The size classes found at all three principal study sites--Kawela Bay, Palaau and Kahului Bay--are compared in Figure 10.

The high proportion of adults present near the outfall was confirmed by estimates of the size of turtles seen surfacing to breathe. It was also verified by skin diving into the plume of clear water and viewing up to 28 turtles (on 2 May 1985) for a short time before they fled. A few turtles in the 45-55 and 55-65 cm size classes, for which no individuals were captured, were in fact seen, but not near the larger turtles. The smallest turtle in the sample (44.8 cm, Table 22) was caught in a net that had been positioned farther seaward from the outfall. Although sufficient data are lacking, there was nevertheless some indication that small turtles <65 cm are restricted to the cooler regions of the discharge. If so, this might be due to territorial behavior by large turtles, or that smaller turtles are less able to tolerate the higher temperatures close to the outfall. This latter possibility would be consistent with thermoregulatory behavior in the Northwestern Hawaiian Islands where turtles <65 cm seldom come ashore to bask. The plume was consistently found to be 30°-31°C at its warmest site during April, May, and June when the field studies were conducted.

The stomach contents sampled from seven of the turtles revealed that four (57%) contained 95% or more Codium edule (Table 23). Another sample consisted of 25% Acanthophora, 25% Amansia, and 50% Laurencia nidifera. Only minute food particles of Pterocladia sp. and Laurencia sp. were in the smallest turtle captured (44.8 cm). An additional 16 other species of benthic algae were identified, but only in trace amounts from the various stomach samples. Two samples also contained a small crab or crab parts which were likely ingested unintentionally along with algae used for food. A nutritional benefit would nevertheless accrue if many of these crustaceans are present on the algae when it is eaten.

The green alga, Chaetomorpha brachygona, was on the carapace of turtles captured near the outfall (Table 9). This genus has not been previously recorded growing on green turtles in Hawaii. In contrast with the other principal study sites, turtles sampled near the outfall had very little or no red algae (Polysiphonia spp.) on their neck and groin. However, the skin barnacle, Platylepas hexastylos, was exceedingly abundant, and some areas of the groin were completely covered. Also, in contrast with the other study sites, turtles examined at the outfall had the burrowing barnacle, Stephanolepas muricata, in moderate numbers (5-10) along the anterior edge of their front flippers. This barnacle is potentially harmful in great numbers because it lives deep in the tissue and derives part of its sustenance from the turtle's blood. It would appear that both Stephanolepas and Platylepas flourish in the warmer water, rather than being adversely affected by it. No dead barnacles were on the turtles to suggest that the higher temperature at the outfall helped to get rid of them. Small schools of the sergeant major, Abudefduf abdominalis, were seen in the clear plume, but there was no indication that they were grazing on the turtles' epizoites.

Five of the nine turtles captured had prominent external injuries or abnormalities (Table 24); three of these had wounds almost certainly caused by a spear or harpoon. Turtles in the warmer part of the discharge are especially vulnerable to attack with a harpoon, since the embankment is directly above them. Another injured turtle that was captured had a blind and atrophied right eye. The cause could not be determined, however, severe eye damage and blindness inflicted by a three-pronged spear have been documented elsewhere in Hawaii. The largest turtle captured, a 96.5 cm adult female (tag No. 8486, Tables 22 and 24), had numerous small fibropapillomas 0.5-3 cm in diameter on the inguinal and axial regions of all four flippers and on both eyes. Nevertheless, it was vigorous when caught in the net and seemed to be in good nutritional condition. On 23 July 1986, 13 months after being tagged, the turtle was reported dead, washed ashore at Nehe Point, 2.2 km to the west of Hobron Point (Fig. 9). The state of decomposition suggested that the turtle had been dead for 5-10 days. The cause of death was not evident, however, some of the tumors are believed to have noticeably increased in size. Two years earlier on 27 July 1984 another large turtle (88 cm) was found dead at Nehe Point. There were tumors on both eyes and the right front flipper was freshly amputated, presumably by a shark. The stomach was filled to capacity with Pterocladia capillacea.

A comparison of the injuries and abnormalities on turtles of different size classes sampled at the three principal study sites is presented in Table 25.

Deep-body temperatures of 28.8° and 27.6°C were recorded in two turtles right after being hand-captured on 18 and 19 June 1985 in the clear plume of the outfall where the temperature was 30°C (Table 13). These turtles may have been in this warmer water for up to 5 h, respectively. The two measurements demonstrate the thermal advantage obtained near the outfall, since the ambient temperature farther from shore was 26.5°C. The benefit would be even greater at other times of the year and during certain weather conditions when the ambient ocean temperature is even cooler. For example, during the early May 1985 field work in Kahului Bay (Table 1) the offshore temperature was found to be 2° cooler or 24.5°C.

Turtles were censused from shore as they surfaced to breathe in an effort to better understand their diurnal activity patterns and behavior in the vicinity of the outfall. Due to turbid water conditions and reflection on the sea surface, the turtles could only be seen when they came up for air. This surface interval was usually very short, lasting only 1-3 s. Nevertheless, the turtles were highly visible during this brief time since, as mouth breathers, their entire head was raised out of the water. The lighter colored areas of the throat and head were especially noticeable at night under the artifical lighting from the power plant and harbor facilities. Small sharks <1 m long were sighted at the surface a few times, but they were easily distinguished from turtles.

On only a few occasions was it possible to identify and keep track of individual turtles to estimate submergence time between breaths. This interval was tentatively determined to be from 1 to 4 min. However, some turtles may have stayed down for a much longer period, as would occur in typical resting habitats. The complicating factor here is that, although some may be on the bottom in a prolonged resting phase, many others outside of the clear plume appear to be actively foraging and therefore taking more frequent breaths. The warmer water may also be an important factor, since a concomitant increase in body temperature and metabolism would necessitate more frequent respiration. To estimate the total number of turtles around the outfall at any given time, sightings made at the surface during a 1-min period would have to be multiplied by the submergence time, which in this case is assumed to be 1 to 4 min. Figure 11 shows the sightings per minute that were recorded at select times on 13 different days during April, May, and June. The highest counts obtained during this period were 12-29 per min with an average 20 per min on the night of 2 May. Using 2.5 min as an average submergence time, an estimated 50 turtles may have been present. The total number of individuals involved could be even higher if a turnover occurs and new turtles arrive and others depart throughout the night. However, this is unlikely to be a significant factor since very few turtles ever reappeared once a major disturbance, like a diver entering the water, frightened them away.

The arrival of turtles near the outfall starting at sunset, and their increase after the end of twilight, are illustrated in Figure 11:1-1C. Also shown here is the approximate 35% decline in sightings that resulted when three persons started fishing from the top of the embankment by casting beyond where the turtles were aggregated. Figure 11:2-2C illustrates a similar scenario on the following night (11 April), only this time a lone fisherman was present from before sunset standing on the boulders right next to the outfall. He departed shortly after dusk at 1930. Until the time he left the turtle sightings remained very low. However, a small but noticeable increase occurred 30-45 min later, even though several other people started fishing 50 m to the east of the outfall in a much less illuminated section of the embankment. Representative sightings taken after dark on 1 May, when no direct human disruption occurred, are shown in Figure 11:3. Similar sightings for the following night appear in Figure 11:4. However, in this case a skin diver (one of the research personnel) spent 15 min surveying the area. As shown, an almost total abandonment of the area by the turtles subsequently took place. Figure 11:5-5A again illustrates a sighting period from sunset until after dark with no human intervention. Figure 11:6-7 covers several censuses during 4-9 May, one of which revealed the near absence of turtles due apparently to two fishermen standing close to the outfall.

The floodlight that normally comes on automatically shortly after sunset was placed on manual control and left off for several hours on the nights of 17-20 June. This was done to try to increase the chances of catching turtles in nets set nightly during this period. It also provided the opportunity to see what effect this point source of illumination might have on the presence of turtles near the outfall. Figure 11:8-10 suggests that little if any response was obtained when the light was switched on. Factors that may be an important consideration here include the array of other lighs in the vicinity, and the apparently exceedingly desirable nature of the heated water to the turtles. Any aversion the turtles may have to shoreline lighting might be overcome by the thermal advantage. It should also be noted that when the floodlight is turned on, it gradually reaches full illumination over a 5-min period, rather than immediate peak intensity. However, this may be of no significance since the headlights from nearby vehicles that sometimes enter the harbor at night periodically flash across the outfall area.

Foraging Habitat Appraisal

Observations made while skin diving at night revealed that the aggregated turtles were not foraging in the warm plume of clear water next to the outfall. Instead, the turtles seen here were either lying motionless on the bottom, or drifting in the shallow water column slowly back and forth along with the wave surge and flow from the outfall. The turtles were also hovering over one another, presumably to obtain maximum use of the warmest portion of the plume. Although the turtles fled within several minutes after the diver's arrival, it was still possible to confirm the absence of any feeding activity, given the excellent underwater clarity within the plume and large numbers (up to 28) viewed each time.

There were no benthic algae growing on the rubble and boulders which comprise the bottom where the highest density of turtles occurred. However, detached pieces of Codium spp. and A. spicifera were abundant. These algae commonly grow along the bottom starting 10-20 m from the clear-water plume and extend up to 300 m from shore. Codium edule and A. spicifera, the two major species in the stomach samples, were especially abundant in a 3 m deep channel present 100-300 m from shore slightly to the west of the outfall. Other algae commonly found included Amansia, Scinaia hormoides, and Dictyosphaeria cavernosa. At dusk turtles were almost always seen surfacing here, apparently occupying or transiting the area before moving closer to the outfall. Foraging seemed likely to occur throughout this rich algal zone, although it is too far away to make observations from shore at night. Turtles that could be seen commonly surfacing in turbid water much closer to the clear plume may have also been feeding on algae growing on the bottom.

Fresh frozen bulk samples of the two principal food sources, as well as another alga, C. reediae, were analyzed to compare nutrient composition (Tables 26 and 27). Codium reediae, although abundant, was not found in any of the stomach samples. The C. edule was harvested from the channel area approximately 200 m from shore, and at a site near the clear plume. The former location was beyond the direct thermal influence of the outfall, and the latter was well within it.

On a dry matter basis, Acanthophora contained more than twice as much protein (Table 26) and iron (Table 27) as C. edule. Acanthophora also had much higher levels of copper, manganese, and zinc than C. edule, but was noticeably lower in sodium, magnesium, and potassium (Table 27). The composition of C. edule, sampled at the two sites, varied for a number of nutrients; concentrations were generally higher in the plants growing close to the outfall. Prominent among these were protein (10.7% vs. 8.2%), fiber (26.6% vs. 21.8%), calcium (5.7% vs. 1.7%), iron (918 vs. 385 ppm), and manganese (425 vs. 44 ppm). The nutritional significance and reasons for these differences are unknown. However, the higher levels of protein might be expected to produce faster rates of growth in turtles utilizing this material. The higher concentrations of certain heavy metals in algae near the outfall could be due to various metallic debris and other litter present along the bottom, or possibly an elevated content in the discharge water.

While diving about 150 m from the outfall, an abandoned gill net was located and removed from the bottom where it had become fouled on calcareous outcroppings. This net was probably the same one in which a large (70-80 cm) turtle was found entangled on 8 October 1984 (see Balazs 1985c:405). Rescuers tried to cut the net loose, but the turtle swam away with a piece of line still wrapped around it's flipper. Other debris of significance found on the bottom included the scute from the carapace of a small (45 cm) turtle.

Many areas along the seaward side of the Kahului Harbor breakwater have dense intertidal growths of Pterocladia. It is especially visible at low tide growing on the light-colored concrete on the west side of the harbor entrance. This alga, along with a band of Ulva fasciata, also occurs on the boulder embankment immediately to the east (upwind) of the warmwater outfall. Although Pterocladia is available here in considerable abundance, the turtles are apparently not utilizing it to any great extent, based on the stomach samples obtained. In an earlier study of resident green turtles at Punaluu Bay on the Island of Hawaii, the sole source of food was Pterocladia. The most rapid growth rates thus far known for green turtles in the Hawaiian Islands occur at this location (Balazs 1982).

Inside the harbor there are profuse growths of U. fasciata on the rocks and other hard surfaces interspersed along the two sand beaches. Accumulations of decomposing Ulva and other algae often occur on this shoreline. In the vicinity of the boat ramp on the harbor's west side there are large quantities of the red alga, Hypnea musciformis. This species was introduced to the Hawaiian Islands from Florida in 1976. It is now sometimes found as a dietary component of green turtles, especially around Oahu (Balazs 1980b).

Turtles are reported to only rarely occur inside the harbor. None was observed during the present study. One person interviewed said that the same large turtle, identifiable by the pattern of barncles on its carapace, has been occasionally seen inside the harbor for the past several years.

Resting Habitat Appraisal

The warmwater area closest to the outfall can, to some extent, be considered resting habitat since most of the turtles seen there were in an inactive "resting" state. The principal motivation for occupying this site, however (other than for nearby foraging) is almost certainly for thermoregulation. That is, to elevate body temperature to accelerate metabolic processes such as digestion, growth, and reproduction. The complete absence of turtles in the vicinity of the outfall during the daytime strongly suggests that resting habitat of a more typical nature is being utilized elsewhere.

Other than the dredged harbor and entrance channel, the nearshore waters of the power plant are relatively shallow, and there is no structural relief along the bottom where turtles might find shelter to rest. Extremely high turbidity and hazardous conditions from vessel traffic prevented scuba diving along the channel entrance to search for resting sites. However, no turtles were seen at the surface in this area, as usually occurs where they rest in numbers along the bottom.

Besides the harbor channel, the nearest area of deep water to the power plant is located 1.0-1.3 km seaward, in a northerly direction beyond the breakers (Fig. 9). Significant resting habitat was identified here which is almost certainly being used by the turtles present at the outfall. The normally strong onshore tradewinds, high turbidity, and wind-driven swell made this area difficult to examine. However, for several hours following sunrise on 9 May 1985 calmer conditions prevailed which allowed a scuba survey to be undertaken.

The bottom outside the breakers was hard and relatively featureless in depths of 4-8 m. However, slightly farther offshore, there was a series of sheer-walled canyons with sand bottoms at depths of 20-25 m. One of these canyons that was no more than 15 m wide was examined by following it along the bottom for about 100 m. Three large turtles >82 cm were encountered resting under or within calcareous recesses in the canyon wall. One turtle was seen as it rapidly swam off, leaving a large cloud of suspended sand. The other two remained in their protective shelters, where they were positioned somewhat sideways and well aware of a diver's presence. One turtle moved a short ways farther into its resting place when the diver touched its flippers to confirm the absence of tags. Due to their large size, no attempt was made to catch the turtles by hand. Outside the canyon, another turtle was lying motionless between outcroppings on the bottom at a depth of 23 m. A fifth turtle was sighted in a shallower area (10 m) between two small live coral heads, but it was alert and immediately swam away. While at anchor and motoring through this offshore area, several turtles were also seen floating at the surface.

Findings at Other Study Sites

Maunalua Bay, Oahu

A popular surfing site known as "Turtles" exists outside the shallow reef flat in Maunalua Bay (lat. 21°17'N, long. 157°45'W) at the southeast end of Oahu (Fig. 12). This place-name appears to be of relatively recent origin having resulted from surfers regularly spotting turtles in the area (Pukui et al. 1976; Aecos 1981). Turtles are reported to have been commonly caught in abundance with nets set on the reef flat prior to major residential development involving the dredging and landfill of fishponds for the Hawaii Kai subdivision. The east side of Maunalua Bay, inside the fringing reef, is now used extensively for recreational purposes, including jet ski rentals and outrigger canoe paddling. A dredged and well-marked boat channel leads through the shallow reef up to an improved boat ramp and also into the Hawaii Kai Marina located inside Kuapa Pond. Clark (1977) and Aecos (1981) provide additional descriptive information on the surrounding coastline and reef, which includes Paiko Peninsula, Kuliouou, Maunalua Bay Beach Park, and the Portlock area of Koko Head.

Commercial scuba diving charters which have used Maunalua Bay during recent years often operate just outside the breakers in the vicinity of the Turtles surfing site. This underwater region has been named "Turtle Canyon" in advertisements and promotional articles appearing in national magazines (Church and Church 1985). The viewing and photography of turtles here has become a popular attraction for tourists and other divers.

Scuba surveys listed in Table 1 that were conducted at Turtle Canyon confirmed the area to be important resting habitat. A series of low calcareous ridges extend along the bottom separated by sand channels 9-11 m deep. Three immature turtles measuring 39, 42, and 62 cm were hand-captured while resting near coral outcroppings that provided a minimum of shelter (Table 28). One turtle had only its head inside a small recess, while another was lying mostly unprotected on a waterlogged palm frond that had settled to the bottom. Virtually no ocean surge could be felt on the bottom where the turtles were resting.

Codium edule and *C. arabicum* were in the stomach contents of the single turtle that was sampled (Table 29). *Codium* was not present in the surrounding area and therefore had likely been eaten on the reef flat in typical foraging habitat located closer to shore. An algal mat growing on the ventral surfaces of the flippers of the 42 cm turtle was identified as *Ectocarpus indicus*. A similar algal growth was present on the other two turtles examined. In addition, all three had small numbers of skin barnacles, *P. hexastylos*, and, on the 42 cm turtle alone, a single burrowing barnacle, *S. muricata*. The 62 cm turtle had a small growth on its right eye and axilla. None of the other seven turtles sighted while diving appeared to have tumors. However, just recently (August 1986) a dive tour operator has reported regularly seeing a severely afflicted small turtle (<55 cm).

A significant, albeit brief, observation made in this area involved three turtles near a prominent coral head surrounded by sand. One of the turtles was seen posturing motionless over the coral while a surgeonfish (probably Ctenochaetus strigosus) grazed on an algal mat growing on the carapace. Discrete underwater cleaning stations for turtles involving surgeonfish, Acanthurus sandvicensis, and wrasses (Labridae) have been observed in the Northwestern Hawaiian Islands (Balazs 1980b:21). Such sites have not been previously documented in resting or foraging habitat of the main islands. Their detection is undoubtedly made difficult by the easily disturbed interspecific behavior of the turtles and fishes. Cleaning symbiosis of this nature may very well play an important role at certain locations in reducing the amount of fouling growth that accumulates on Hawaiian green turtles.

West Beach, Oahu

West Beach is the name recently given to a large parcel of agricultural land fronted by 3 km of shoreline at lat. 21°21'N, long. 158°08'W on the southwest leeward coast of Oahu (Fig. 13). The southern boundary of the area is the Barbers Point Deep Draft Harbor which is presently under construction. The northern limit is Lanikuhonua, an historic beachfront estate now called Paradise Cove where Hawaiian luaus are held for tourists. The West Beach shoreline consists mainly of a limestone bench 3-4 m high with pockets of sand behind it. Freshwater springs percolate into the sea at several sites along here. A dense growth of Pterocladia capillacea occurs in the lower portion of the intertidal zone along much of the bench. However, this alga is not present within about 200 m of the entrance to the deep draft harbor, nor immediately to the south of it. It does occur along the shoreline to the north of Lanikuhonua to Kahe Point. An underwater coastal shelf extends for 1.5-2.0 km off West Beach, but no fringing or barrier reef exists to buffer southerly ocean swells. Consequently the waves break close to shore often directly upon the limestone bench.

An extensive urban, residential, and resort development is planned for West Beach in the near future. Included will be the excavation of four 0.8-2.2 ha swimming lagoons with flushing channels cut through the shoreline, as well as a 500-berth marina using the newly dredged entrance channel of the Deep Draft Harbor. An analysis of the biological impacts of constructing the lagoons and marina has been prepared with special emphasis on the nearshore environment of the limestone bench (OI Consultants, Inc. 1984). However, green turtles and their foraging habitat were not covered in this document. In the past, from the mid-1940's through the 1960's, anecdotal reports indicate that large numbers of turtles were fished commercially from nearshore waters extending from Barbers Point northward to Kahe Point (Fig. 13).

Shoreline surveys shown in Table 1 made at West Beach during periods of sunrise and sunset resulted in few turtles (0-5) being sighted each time. None surfaced close to the limestone bench, although foraging may have occurred there prior to dawn when it was too dark for turtles to be visible. A skin diving survey conducted on 2 April 1985 in waters within 50 m of the bench revealed considerable structural relief to the bottom. There were numerous areas that appeared suitable for turtles to rest, but no turtles were seen. Similar bottom habitat is reported to exist for up to 500 m seaward in depths of 4-7 m.

As found elsewhere, the growth of Pterocladia was restricted to a very narrow zone immediately along the limestone bench. Other algae that might be used as food sources by turtles were not present within the area surveyed. It is of interest to note that masses of monofilament line with sinkers attached were commonly found tangled along the bottom close to shore. This debris illustrates the area's popularity for shoreline fishing.

On 8 August 1985 scuba diving was conducted off the entire West Beach coastline along the 18 m drop-off. Several caves and ledges were encountered that appeared suitable as resting habitat, but no turtles were seen, either underwater or at the surface. Potential resting sites were more plentiful during similar searches along the drop-off to the south of the Deep Draft Harbor. Four turtles were seen here underwater, two of which were resting together in a large cave. One had a tumor on its left eye and front flipper. A fifth turtle was seen at the surface.

Significant numbers of turtles apparently no longer occur along West Beach and the adjacent shoreline to the south and north. However, both the offshore resting areas and nearshore foraging habitat presently seem to be intact and available for use. One area worth investigating would be to ascertain the magnitude of predation on turtles by tiger sharks along this coastline. Large sharks are believed to be more abundant in the Barbers Point area due to their attraction to tankers that anchor offshore while delivering oil to the nearby refinery. High predation by tiger sharks could be suppressing the successful recruitment rate of small turtles into this benthic coastal habitat.

Sandy Beach, Oahu

Sandy Beach is a popular body surfing and swimming site located at lat. 21°17'N, long. 157°41'W on the east end of Oahu along the windswept Kaiwi Channel (Fig. 14). The area is part of a City and County regional park. Prior to the opening of a coastal road in 1931, the area was only accessible by foot trail (Clark 1977). The sand beach itself is 365 m long and often has a dangerous shore break with strong offshore currents. Each end of the beach is bordered by rough lava that juts into the sea. An underwater discharge pipe for a nearby sewage treatment plant extends 500 m seaward near the north end. Surfers periodically report seeing turtles off Sandy Beach, but the area is not known to host a significant aggregation, nor is there a history of such an occurrence.

The purpose of focusing attention on this site for the present study was the somewhat fortuitous observations made of two small turtles foraging close to shore over a 1-h period. On 16 May 1985, at 1400, two 35-40 cm turtles were watched as they repeatedly swam into the intertidal splash zone to reach a small patch of Ulva fasciata growing on a rocky outcropping in the sand. The location was at the north end of the beach where the wave action close to shore is partly buffered by the adjacent lava rock point.

A high tide of 0.52 m (1.7 ft) occurred at about the same time of the observations. Numerous people were in the vicinity sunbathing, swimming, and riding surfboards on small waves a short distance from shore. In spite of this activity, the turtles periodically swam up to the beach for the Ulva whenever sufficient depth resulted from incoming waves. Since this small foraging site was exposed much of the time, it is likely that the turtles were also feeding on detached pieces scattered along the sand bottom. At no time did the turtles move more than 15 m from shore or into water over 1 m deep. The turtles were highly visible while at the surface and attracted the attention of a number of people. Two men with skin diving gear standing in shallow water initially showed interest in catching them by hand. However, no attempt was carried out, probably due to turbid water conditions and the agility of the turtles.

These observations are worth documenting because the turtles were very likely neophyte recruits to coastal habitat, possibly having only arrived from the pelagic environment within the past day or two. Their small size, boldness near humans, and aggressive foraging behavior in the middle of the day were strongly suggestive of turtles in a famished state unaccustomed to benthic habitat. Previous observations of this nature have not been reported, although the recruitment of small turtles to foraging pastures in the Hawaiian Islands must be a common, or at least a seasonal, occurrence. More work is needed to determine what attributes may attract small pelagic turtles into a particular benthic habitat where the critical change from a carnivorous to a herbivorous diet first occurs. Some important considerations would include fluctuations in dispersal patterns due to currents, olfactory cues emanating from foraging pastures such as from algae, turtles already in residence (i.e., from fecal matter), and even freshwater discharge that can sometimes be detected at the ocean surface many miles from shore. An additional important factor may be the increased vulnerability of new recruits to predation from tiger sharks and humans.

An understanding of what prompts turtles to live in a particular foraging pasture, and how well they survive soon after arrival, could have significant management implications. For example, a technique might then be developed to induce captive reared (head-started) turtles to reside in the area selected for their release.

Honokowai, Maui

Honokowai is the site of a small residential and resort community located at lat. 20°57'N, long. 156°42'W on the west side of Maui (Fig. 15). Much of this coastline from Lahaina through Kaanapali and beyond Honokowai has been developed into a major tourist resort area. The shoreline at Honokowai consists of a low limestone shelf backed by a narrow strip of white sand along Honokowai Beach Park. Apartment buildings located immediately to the north of the beach park have a series of cement seawalls built along the water's edge. Clark (1980) reports that Honokowai means "bay for drawing water," and that this site was a Hawaiian canoe landing where freshwater springs occurred. Some freshwater discharge may still take place, but it was not evident during the present study.

Surveys were conducted at Honokowai to follow up on sighting reports received from Burgess Heacock, a tourist who resides at the beach-front Pikake Apartment during January and February of each year. In 1984 and 1985 he made counts of turtles in the vicinity of the apartment each morning for 1-2 h following sunrise. The turtles were mostly seen just past the breakers 50-200 m from shore. With very few exceptions, no turtles were sighted at other times of the day. The number estimated to be present each morning ranged up to 12, but on most days it was 3-4. Similar censuses made by Heacock more recently (January-February 1986) found that probably no more than four turtles were present on any one morning. During most mornings (30 out of 48 days) no turtles were sighted at all. This substantial decline from the previous 2 years was attributed by the observer to firsthand reports of increased numbers of the turtles being captured in the area.

Observations made from shore in front of the apartment shortly after sunrise on 11 April 1985 (Table 1) resulted in only two turtles being seen, both of which were beyond the breakers. Skin diving conducted out to the breakers on the same morning revealed dense growths of algae, especially _Codium_ spp., _Gelidium_ sp., _Acanthophora_, and _Pterocladia_ with entangled _Ulva reticulata_ often growing on it. The depth in most of this area was only 1.0-1.5 m, with many calcareous outcroppings covered with _Pterocladia_ exposed at low tide. The abundance of known food sources that exists at this site is undoubtedly correlated to the presence of turtles previously seen by Heacock. Algal growth was substantially less on the adjacent reef flat surveyed several hundred meters to the north and south.

Large outcroppings of live coral composed of _Porites lobata_ and _P. compressa_ were found while scuba diving outside the breakers in depths of 7-9 m. A barren sand bottom surrounds these 1-2 m high coral mounds and continues seaward with a gradual increase in depth and the disappearance of coral. The structural relief provided by the outcroppings affords excellent sites for turtles to rest, particularly along the undercut interfaces with the sand bottom. However, no turtles were seen during the scuba surveys, even though this zone is the only likely resting habitat in the vicinity.

A number of interesting enigmas exist for the Honokowai site, some of which may be resolved by future reports from Heacock. Additional diving surveys need to be undertaken, if and when the number of turtles returns to the levels seen by Heacock in January-February of 1984 and 1985.

Maliko Bay, Maui

Maliko Bay, located on Maui's north coast at lat. 20°49'N, long. 156°38'W, is a small narrow bay 100-250 m wide and 500 m long with steep rocky sides formed by the Maliko Gulch (Fig. 16). The area is undeveloped except for a cement boat ramp which is accessible by a dirt road leading from the nearby main coastal highway. The shoreline consists of basalt ledges and cliffs, and a water-worn boulder beach where the Maliko Stream empties into the bay. Clark (1980) states that large northerly waves can create powerful rip currents at the entrance to the bay and that surf sometimes breaks entirely across it.

Two recent guidebooks for recreational scuba diving in the Hawaiian Islands make reference to turtles off the east side of the entrance to Maliko Bay. Thorne (1983) mentions that "lots of turtles" can be found there, while Thorne and Zitnik (1984) state "look for the really deep crevasses. They're home for a number of large sea turtles almost always seen here. Some of them are so approachable, you can swim right up and pet them!" This latter publication gives a good summary on the protected status of turtles under Federal and state law, as well as other fishery regulations that should be known by divers in the Hawaiian Islands. In contrast, another recent guidebook fails to say that turtles are legally protected even though it describes in detail where they can often be found, and shows a scuba diver on the front cover reaching for a turtle (Hoffman 1984).

The region at Maliko Bay described by Thorne and Zitnik (1984) was examined on 3 May 1985 using the dive map shown in their publication. Two narrow underwater terraces were found inside the bay along the east side where steep walls descend 10 m to the sandy bottom of the stream bed. The water near the surface was substantially cooler due to the stream's discharge and also probably from freshwater springs in the area. Water was seen dripping from cliffs over the bay's entrance on the west side.

Extensive coral cover exists to about 9 m deep on the numerous submerged ledges and boulders along the entrance on the east side of the bay and extending out to a cluster of rocks awash just offshore. From 9 m down to the sand bottom at 20 m the boulders and rock cliffs are mostly barren. Four turtles were seen on the scuba survey, all of which were outside the bay along the base and walls of the offshore rocks. Three were 55-65 cm, and one was identified as a male 75-85 cm. The latter turtle was resting in one of the deep fissures mentioned by Thorne and Zitnik (1984). The other three were swimming slowly away along the cliff face as the divers approached. Surface weather conditions and other constraints did not permit an exhaustive search of the area. It was estimated that about half of the available habitat was seen. However, within this limited space there appeared to be numerous sites ideally suited for turtles to rest.

During both the scuba survey, and skin diving done earlier on 12 April, the only apparent algal food source for turtles was Pterocladia. None was present near the entrance on the east side of the bay immediately above the turtles' resting areas. However, most of the ledges in the intertidal zone on the west side of the bay had very dense growths of this alga. Large quantities of forage were therefore available in proximity to the turtles, although its accessibility could become restricted at times during the winter months by northerly surf.

Olowalu, Maui

Olowalu, located at lat. 20°49'N, long. 156°38'W, on the southwest side of Maui is a coastal area comprised mainly of sugarcane fields and a prominent offshore reef (Fig. 17). The main highway between Lahaina and Kahului passes through here. The ruins of a former sugar mill and wharf facility exist near the northern end of the reef. The nearshore area of the Olowalu reef on the east side of Hekili Point is easily assessible from shore and is a popular place for skin divers and beginning scuba divers. Both Thorne and Zitnik (1984) and Church and Church (1985) mention that turtles are among the marine life seen there.

In the past, large turtles were reported to have been commercially captured by scuba diving at the 15-18 m drop-off along the seaward edge of the Olowalu reef. One local resident, who was involved in this fishery, said that many turtles previously occurred along here. Capture methods while diving included the use of a noose and gaff to restrain and haul turtles to the surface, or a bangstick (underwater firearm) to dispatch them. However, long before the availability of scuba in the Hawaiian Islands, "several tons" of turtle were being caught each day for the Honolulu market by resident Japanese fishermen using large nets and diving along Maui's southwest coast (Anon. 1918).

Scuba surveys were made on 8 May 1985 on the west side of Olowalu reef, starting in water 6 m deep and proceeding out and along the 15-18 m contour line. Only one turtle was seen during 3 man-hours of diving. It was estimated to be 45-55 cm and, when first sighted, was resting on the bottom on a mound of coral debris.

A major feature of the reef to the southeast of Olowalu wharf (Fig. 17) was the scarcity of live coral. Many canyons consisting of sand channels and calcareous ridges were present. However, the dominant _Porites_ spp. corals were mostly dead and fractured. There were very few places in which the structural relief had not collapsed and ruined the undercuts and ledges favored by turtles for resting. This damage had likely resulted from a large storm, possibly Hurricane Iwa in November 1982. Virtually the only alga seen in this area was _Liagora papenfussi_, which is not a known food source for turtles.

The region directly south and to the east of the wharf consisted mainly of hard, smooth bottom having a moderate seaward slope and no discrete drop-off. _Spyridia filamentosa_ was commonly growing on the bottom at depths of 11-14 m.

Keomuku, Lanai

Keomuku is the name of a deserted village and coastal area located at lat. 20°51'N, long. 156°50'W on the northeast side of Lanai (Fig. 18). A sugarcane plantation was started there in 1899, but was abandoned 2 years later due to a plague epidemic and freshwater irrigation wells that turned brackish. The only land access to the area is by dirt road in a four-wheel drive vehicle traveling 20 km from Lanai City, located in the center of the island. Nearly all of the island's 2,500 inhabitants live in Lanai City where a pineapple plantation has been centered since the 1920's.

The shoreline at Keomuku consists of a narrow terrigenous sand beach backed by thick kiawe and mountain slopes. A shallow and mostly silt-laden reef flat 400-800 m wide borders the region and extends almost continuously for 22 km from Halepalaoa through Keomuku to Polihua on the island's northwest shore (Figs. 18, 19, and 20). According to Clark (1980), 150 m of new land has accrued in front of the old village since 1935 due to soil runoff from the severe erosion affecting much of the island. The remains of two Hawaiian fishponds (Waiopae and Kaa Ponds) are located near here.

During the 1960's and early 1970's turtles were intensively captured off the Keomuku reef by commercial fishermen from Maui. The Auau Channel, which separates Lanai from Maui by only 13 km, is substantially protected from strong tradewinds and therefore usually calm enough to cross in a small boat. Most of Lanai's remote coastal waters along the east and south shores are accessible by this route. In addition, when the tradewinds are absent, the reefs off the entire remote northern coast of Lanai are also accessible by boat from Maui as well as Molokai. The methods used to catch turtles off Keomuku in the past consisted of scuba diving with a noose, gaff, or powerhead. Most of the turtles taken here were sold to restaurants on Maui and Oahu that catered to the tourist trade.

Keomuku is currently a popular destination for dive charters originating from across the channel at Lahaina. Turtles play a prominent role in some of these tours with dive shops naming and advertising such sites as "Turtle Heaven" and "Turtle Town" (Church and Church 1985). Reports have been made by dive shop personnel of up to 30 turtles (mostly small ones) being seen at certain locations during a 40-50 min scuba dive. Descriptions of the turtles' behavior suggest that cleaning stations may be involved in some of these sightings. At Halepalaoa, the southern limit of Keomuku and former sugar plantation landing, the entrance channel has recently been cleared of coral heads and a small pier constructed for tourists to go ashore.

The seaward edge of the fringing reef along Keomuku was examined by scuba and skin diving on 4 and 6 May 1985 using a Zodiac to reach the area from Maui. No surveys were made inshore on the shallow reef flat. Along the section of fringing reef designated as Turtle Heaven fronting the old village (Fig. 18), seven turtles were seen and three others captured during 4 man-hours of scuba diving (Table 28). The seawater temperature was 25°C. All size classes appeared to be represented in the sample of 10 turtles. The largest turtle captured was 76 cm, but a larger one believed to be >82 cm was seen near the bottom of the drop-off at 18 m.

The three turtles captured were resting under outcroppings of live coral in narrow sand channels 2-4 m wide which descend rapidly from the outer reef edge to the drop-off. Many such channels exist along here with coral outcroppings of <u>Montipora</u> <u>dilitota</u>. The preferred resting sites appeared to be between 8 and 13 m deep. A high percentage of live coral cover and structural relief occur throughout this entire zone. However, at the base of the drop-off the bottom consists of featureless rubble and sand.

A fourth turtle (52 cm) was captured and five others seen, all 45-55 cm, while skin diving in water 6 m deep just north of Halepalaoa where the fringing reef starts. One turtle was swimming slowly in a school of several dozen surgeonfish, A. sandvicensus, but no cleaning symbiosis was evident.

Stomach samples taken from two turtles were comprised almost entirely of Amansia (Table 29). Five other species of algae, including Acanthopora, occurred in only trace amounts.

Two 39 cm turtles were found washed ashore at Keomuku at about the same time the diving surveys were conducted. One was dead and the other was barely alive but died the following day. The turtles were shipped frozen to Honolulu by personnel of the State of Hawaii Division of Conservation and Resources Enforcement. A necropsy examination was subsequently conducted, but the cause of death could not be determined. One turtle had been feeding almost entirely on Acanthophora (Table 29). The stomach of the other turtle contained numerous partially digested pieces of the filefish, Pervagor spilosoma. In contrast, this same turtle's intestines were filled with Amansia but only had small amounts of fish bones. Large numbers of P. spilosoma occur cyclically in Hawaiian waters, often accompanied by mass die-offs and many fish washing ashore. During the present study P. spilosoma was commonly seen while scuba diving. In spite of their herbivorous nature in benthic habitat, green turtles, especially small ones, will feed on animal material if it becomes readily available. This undoubtedly happened in the case at Keomuku, although it is unknown if the ingestion of filefish was related to the turtle's death.

The only algal food source located along the outer slope of the fringing reef was Amansia. In front of the old village it was present in abundance growing mostly in shaded crevices 4-6 m deep. Many of these plants were covered with a fine layer of silt.

Kuahua, Lanai

Kuahua is a small point of land on the wind swept northern coast of Lanai at lat. 20°55'N, long. 156°55'W along what is known as Shipwreck Beach (Fig. 19). The fringing reef here extends for up to 500 m from shore and is a continuation of the one bordering Keomuku. The shoreline is characteriaed by outcroppings of basalt and limestone, terrigenous sand beaches, and kiawe. As the name Shipwreck Beach implies, numerous vessels have grounded in the vicinity dating back to the 1820's. Clark (1980) reports that, in addition to maritime accidents, many of these wrecks resulted from the deliberate disposal of unwanted vessels. Another source of this coastal debris comes from high seas flotsam being funneled towards northern Lanai by currents and strong tradewinds passing through the narrow Pailolo Channel which separates Maui and Molokai (Fig. 19). This same pathway may also play an important role in transporting pelagic turtles into the coastal benthic habitats of northern and eastern Lanai and the south shore of Molokai.

The most prominent shipwreck visible along northern Lanai (or anywhere else in the Hawaiian Islands) is ca. 75 m transport vessel that grounded on the reef in 1960 on the east side of Kuahua. A dirt road ends nearby at a small cluster of beach shacks called Federation Camp. These dwellings are used by residents of Lanai City on weekends and holidays for recreation and fishing. They were built by members of the island's large Filipino community, reportedly using lumber salvaged from a shipwreck during the 1950's.

The reef between Kuahua and Federation Camp, a distance of about 1 km, is reported to be an area where turtles regularly occur. According to some residents this site is second in importance only to Keomuku as a place where turtles can be found on Lanai. Gill nets set on the reef at both locations are known to catch and drown small turtles. In addition, it is not uncommon for skin divers from Federation Camp to encounter turtles while spear fishing. A woman interviewed complained that when fishing from shore near Federation Camp turtles sometimes take bait from her line.

Observations made from shore between Kuahua and Federation Camp on 10-12 July 1985 revealed the presence of turtles feeding in the late afternoon through sunset. All of the turtles were within 30 m of land in water 0.4-1.5 m deep, and most appeared to be small (35-55 cm). The greatest number sighted during an observation period was estimated to be 11.

Two of four turtles seen feeding within 2 m of shore in water only 0.4 m deep were hand-captured at 1830 on 11 July (Table 28). Algae collected from their mouths were identified as mostly *Acanthophora*, *Ulva fasciata*, and *Hypnea musciformis*, the recently introduced alga from Florida (Table 29). The turtles' foraging site was confined to a relatively small area adjacent to a low limestone bench bordering the shoreline in the intertidal splash zone. Small seeps of fresh water occurred in the sand behind this bench. Bees were attracted to the water, and the tracks of deer and birds were present around it. Fecal matter from these animals may provide added fertilizers for the nearby algae. *Enteromorpha tubulsa*, a bright green alga present on the elevated portions of the limestone bench, would also be a likely beneficiary.

Benthic algae were seen in abundance throughout most of the reef while skin diving inside the breakers in depths <3 m. However, unlike the near-shore foraging site, the algae consisted of *Dictyota acuteloba*, *Spyridia filamentosa*, *Lyngbya majucula*, *Laurencia* sp., and *Nemalion* sp. Some live corals were present, but the bottom was comprised mostly of calcareous rock, rubble, and fine sediments from coastal run-off. Two turtles were seen underwater, both of which were 35-45 cm. They were resting on the bottom at a depth of 4.5 m just outside the breakers about 30 m west of the grounded vessel.

Polihua Beach, Lanai

Polihua Beach is located on the northwest shore of Lanai at lat. 20°55'N, long. 157°03'W, about 20 km across the Kalohi Channel from Palaau on Molokai. The beach is 1.8 km long, up to 100 m wide, and composed of white and brownish sand with reddish areas caused by the run-off of fine terrigenous material. The east and west ends are bordered by outcroppings of basalt. There is no protective reef and strong offshore currents are reported to exist throughout the year (Clark 1980). The dominant vegetation growing behind the beach is kiawe. Strong tradewinds occur much of the time and gusts frequently pick up clouds of stinging sand. Dunes estimates to be 10-15 m high exist within the vegetation zone at the east end of the beach. Access to Polihua is by four-wheel drive vehicle over a dirt road leading 18 km from Lanai City.

Polihua Beach is the only site in the main Hawaiian Islands with a well-documented history of nesting by green turtles. It is also the only location where the traditional Hawaiian place-name is descriptive of eggs on a beach (Polihua means literally "eggs in bosom," Pukui et al. 1976). The available information indicates that Polihua was an important breeding site for the green turtle until the late 1800's or early 1900's. Since then very little nesting has been reported to occur there. The existing knowledge covering the historical, cultural, and ecological aspects of turtles at Polihua have recently been summarized in Balazs (1985a). Six cases of possible nesting since 1954 were identified based on prior interviews and correspondence with residents who had visited the beach for fishing and camping.

An inspection of Polihua was made on 8-10 July 1985, since any nesting taking place would be most likely to occur during June and July. No signs of previous nesting were detected, and no turtles came ashore during comprehensive beach patrols made on two consecutive nights. Considerable human use of the area was noted, including vehicle tracks along the beach, rubbish at numerous camping sites, and the butchered remains of a deer. In addition, a 7-m Zodiac from Maui passed close to the beach taking tourists on a sightseeing trip around Lanai. Earlier reports indicated that a helicopter tour service was periodically landing at Polihua, but no evidence of this was found.

The beach environment at Polihua is heavily influenced by sedimentation, much of which comes from runoff down the steep dirt access road bulldozed some years ago. Adjacent gulches also transport soil from the severely eroded upper slopes during heavy rain. Several sites along the beach within 25 m of the vegetation line were covered with ooze as well as dried, cracked deposits of mud. The roots of kiawe trees also affect this upper beach zone where turtles would be expected to nest. A dense network of roots was often present, both underground and along the surface, forming a barrier that would be difficult for a nesting turtle to penetrate.

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LITERATURE CITED

Aecos, Inc.
1981. Oahu coastal zone atlas. Produced for the U.S. Army Corps of Engineers by Aecos, Inc., Kailua, Hawaii, 93 maps.

Anonymous.
1918. Turtle fisherman making good money. Maui News, 12 April, p. 2.

Apple, R. A., and W. K. Kikuchi.
1975. Ancient Hawaii shore zone fishponds: An evaluation of survivors for historical preservation. U.S. Dep. Interior, Natl. Park Serv., Honolulu, 157 p.

Armstrong, R. W. (editor).
1983. Atlas of Hawaii. Univ. Hawaii Press, Honolulu, 2d ed., 238 p.

Balazs, G. H.
1976. Green turtle migrations in the Hawaiian Archipelago. Biol. Conserv. 9:125-140.

1978. Terrestrial critical habitat for sea turtles under United States jurisdiction in the Pacific region. 'Elepaio 39(4):37-41.

1980a. Field methods for sampling the dietary components of green turtles, <u>Chelonia mydas</u>. Herpetol. Rev. 11(1):5-6.

1980b. Synopsis of biological data on the green turtle in the Hawaiian Islands, U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-7, 141 p.

1982. Growth rates of immature green turtles in the Hawaiian Archipelago. <u>In</u> K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 117-125. Smithson. Inst. Press, Wash., D.C.

1983. Recovery records of adult green turtles observed or originally tagged at French Frigate Shoals, Northwestern Hawaiian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-36, 42 p.

1985a. History of sea turtles at Polihua Beach on northern Lanai. 'Elepaio 46(1):1-3.

1985b. Status and ecology of marine turtles at Johnston Atoll. Atoll Res. Bull. 285:1-46.

1985c. Impact of ocean debris on marine turtles: Entanglement and ingestion. <u>In</u> R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris 27-29 November 1984, Honolulu, Hawaii, p. 387-429. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Balazs, G. W.
1986a. Fibropapillomas in Hawaiian green turtles. Mar. Turtle Newsl. 39:1-2.

1986b. Resuscitation of a comatose green turtle. Herptol Rev. 17(4): 79-80.

Balazs, G. H., and W. G. Gilmartin.
1985. A suggested modification of tagging pliers. Mar. Turtle Newsl. 34:2-3.

Barnard, J. L.
1967. A new genus of Galapagan amphipod inhabiting the buccal cavity of the sea-turtle, Chelonia mydas. Proceeding of Symposium on Crustacea, Part 1:121-125.

Bentley, T. B., and A. Dunbar-Cooper.
1980. A blood sampling technique for sea turtles. Final Report for contract No NA-80-GE-A-00082. Southeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 14 p.

Bjorndal, K. A.
1980. Nutrition and grazing behavior of the green turtle, Chelonia mydas. Mar. Biol. (Berl.) 56:147-154.

1982. The consequences of herbivory for the life history pattern of the Caribbean green turtle, Chelonia mydas. In K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 111-125. Smithson. Inst. Press, Wash., D.C.

1985. Nutritional ecology of sea turtles. Copeia 1985:736-751.

Carr, A.
1980. Some problems of sea turtle ecology. Am. Zool. 20:489-498.

Carr, A., M. H. Carr, and A. B. Meylan.
1978. The ecology and migrations of sea turtles, 7. The west Caribbean green turtle colony. Bull. Am. Mus. Nat. Hist. 162:1-46.

Carr, A., A. Meylan, J. Mortimer, K. Bjorndal, and T. Carr.
1982. Surveys of sea turtle populations and habitats in the western Atlantic. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SEFC-91, 82 p.

Church, J., and C. Church.
1985. Hawaiian Islands: America's paradise in the Pacific. Skin Diver 34(3):34-56.

Clark, J. R. K.
1977. The beaches of Oahu. Univ. Hawaii Press, Honolulu, 193 p.

1980. The beaches of Maui County. Univ. Hawaii Press , Honolulu, 161 p.

Coston-Clements, L., and D. E. Hoss.
1983. Synopsis of data on the impact of habitat alteration on sea turtles around the southeastern United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-SEFC-117, 57 p.

Coulter, J. W. (compiler).
1935. A gazetteer of the Territory of Hawaii. Univ. Hawaii Res. Publ. 11, 241 p.

Dizon, A. E., and G. H. Balazs.
1982. Radio telemetry of Hawaiian green turtles at their breeding colony. Mar. Fish. Rev. 44(5):13-20.

Doty, M. S.
1961. Acanthophora, a possible invader of the marine flora of Hawaii. Pac. Sci. 15(4):547-552.

Ehrhart, L. M.
1983. Marine turtles of the Indian River lagoon system. Fla. Sci. 46(3/4):337-346.

Frazer, N. B., and L. M. Ehrhart.
1985. Preliminary growth models for green, Chelonia mydas, and loggerhead, Caretta caretta, turtles in the wild. Copeia 1985:73-79.

Hawaiian Electric Co., Inc., and Bernice P. Bishop Museum.
1975. A survey of the marine benthos in the vicinity of the Kahului generating station, 155 p.

Hirth, H. F.
1971. Synopsis of biological data on the green turtle Chelonia mydas (Linnaeus) 1758. FAO Fish. Synop. 85,1:1-8:19.

Hirth, H. F., and A. Carr.
1970. The green turtle in the Gulf of Aden and the Seychelles Islands. Verh. K. Ned. Akad. Wet. Afd. Natuurkde. Tweede Reeks 58:1-44.

Hirth, H. F., L. G. Klikoff, and K. T. Harper.
1973. Sea grasses at Khor Umaira, People's Democratic Republic of Yemen with reference to their role in the diet of the green turtle, Chelonia mydas. Fish. Bull., U.S. 71:1093-1097.

Hoffman, P.
1984. Comprehensive guide to scuba diving in Hawaii. Press Pacifica, 111 p.

Hopkins, S. R., and J. I. Richardson (editors).
1984. Recovery plan for marine turtles. Prepared by the U.S. Marine Turtle Recovery Team. Approved September 9, 1984 by the National Marine Fisheries Service, 355 p.

Ireland, L. C.
1979. Homing behavior of juvenile green turtles, Chelonia mydas. In C. J. Amlaner, Jr., and D. W. MacDonald (editors), A handbook of biotelemetry and radio tracking, p. 761-764. Pergamon Press, Oxford.

Johannes, R. E.
1980. The ecological significance of the submarine discharge of groundwater. Mar. Ecol. Prog. Ser. 3:365-373.

Legler, J. M.
1977. Stomach flushing: A technique for chelonian dietary studies. Herpetologica 33:281-284.

Limpus, C. J., A. Fleay, and M. Guinea.
1984. Sea turtles of the Capricornia Section of the Great Barrier Reef Marine Park. In W. T. Ward and P. Saenger (editors), The Capricornia Section of the Great Barrier Reef, p. 61-78. R. Soc. Queensl. Aust. Coral Reef Soc., Brisbane.

Limpus, C. J., and P. C. Reed.
1985. The green turtle, Chelonia mydas in Queensland: A preliminary description of the population structure in a coral reef feeding ground. In G. Grigg, R. Shine, and H. Ehmann (editors), Biology of Australasian frogs and reptiles, p. 47-52. R. Zool. Soc. N.S.W.

MaGruder, W. H., and J. W. Hunt.
1979. Seaweeds of Hawaii. Oriental Publ. Co., Honolulu, 116 p.

Mendonca, M. T., and L. M. Ehrhart.
1982. Activity, population size and structure of immature Chelonia mydas and Caretta caretta in Mosquito Lagoon, Florida. Copeia 1982:161-167.

Mortimer, J. A.
1981. The feeding ecology of the west Caribbean green turtle (Chelonia mydas) in Nicaragua. Biotropica 13:49-58.

Mower, H. F.
1983. Mutagenic compounds contained in seaweeds. In H. F. Stich (editor), Carcinogens and mutagens in the environment. Naturally occurring compounds Vol. 3. CRC Press, Boca Raton, Florida, p. 81-85.

Oceanit Laboratories, Inc.
1985. An ocean engineering study of Kawela Bay, Oahu, Hawaii. Prepared for The Prudential Insurance Company of America. Oceanit Laboratories, Inc., Box 10333, Honolulu, HI 96816.

Ogden, J. C., L. Robinson, K. Whitlock, H. Daganhardt, and R. Cebula.
1983. Diel foraging patterns in juvenile green turtles (Chelonia mydas L.) in St. Croix United States Virgin Islands. J. Exp. Mar. Biol. Ecol. 66:199-205.

OI Consultants, Inc.
1984. Analysis of biological impacts of the lagoon/marina development at West Beach, Oahu, Hawaii. 17 p. + appendix A, 60 p.

Owens, D. W., and G. J. Ruiz.
1980. New methods of obtaining blood and cerebrospinal fluid from marine turtles. Herpetologica 36:17-20.

Pukui, M. K., S. H. Elbert, and E. T. Mookini.
1976. Place names of Hawaii. Univ. Press Hawaii, Honolulu, 289 p.

Rand, T. G., and M. Wiles.
1985. Histopathology of infections by _Learedius learedi_ Price, 1934 and _Neospirouohis schistosomatoides_ Price, 1934 (Digenea: Spiorchidae) in wild green turtles, _Chelonia mydas_ L., from Bermuda. J. Wildl. Dis. 21:461-463.

Ross, J. P.
1985. Biology of the green turtle, _Chelonia mydas_, on an Arabian feeding ground. J. Herpetol. 19:459-468.

Russell, D. J.
1981. The introduction and establishment of _Acanthophora spicifera_ (Vahl) Boerg. and _Eucheuma striatum_ Schmitz in Hawaii. Ph.D. Thesis, Univ. Hawaii, Honolulu, 508 p.

Shabica, S. V.
1982. Planning for protection of sea turtle habitat. _In_ K. A. Bjorndal (editor), Biology and conservation of sea turtles, p. 513-518. Smithson. Inst. Press, Wash., D.C.

Summers, C. C.
1964. Hawaiian fishponds. Bernice P. Bishop Mus. Spec. Publ. 52, Honolulu, 26 p.

Summers, C. C.
1971. Molokai: A site survey. Bernice P. Bishop Mus., Pac. Anthropol. Rec. 14, 239 p.

Taylor, E. A.
1936. Ka wai o ke kala: the water of forgiveness. Paradise of the Pacific 48(9):1.

Thayer, G. W., D. W. Engel, and K. A. Bjorndal.
1982. Evidence for short-circuiting of the detritus cycle of seagrass beds by the green turtle, _Chelonia mydas_ L. J. Exp. Mar. Biol. Ecol. 62:173-182.

Thorne, C.
1983. A comprehensive guide to over 50 locations for scuba diving and snorkeling on the Island of Maui. P. O. Box 223, Kihei, Maui, 67 p.

Thorne, C., and L. Zitnik.
1984. The divers' guide to Hawaii, 248 p.

Wester, L.
1981. Introduction and spread of mangroves in the Hawaiian Islands. Association of Pacific Coast Geographers Yearbook 43:125-137.

Wetherall, J. A.
1983. Assessment of the stock of green turtles nesting at East Island, French Frigate Shoals. Natl. Mar. Fish. Serv., NOAA, Southwest Fish. Cent. Honolulu Lab., Honolulu, HI 96822-2396, Admin. Rep. H-83-15, 16 p.

Whittow, G. C., and G. H. Balazs.
1982. Basking behavior of the Hawaiian green turtle (*Chelonia mydas*). Pac. Sci. 36:129-139.

Wolke, R. E., and D. R. Brooks.
1982. Spirochidiasis in loggerhead sea turtles (*Caretta caretta*): Pathology. J. Wildl. Dis. 18(2):175-183.

Wood, J. R., and F. E. Wood.
1983. Recent developments in the anesthesia of sea turtles. Mar. Turtle Newsl. 26:6-7.

Yoneyama, T.
1985. Kawela Bay: stormy or fair? Honolulu Magazine 20:48-50, 71-72, 74-75, 79-80.

Zug, G., and G. H. Balazs.
1985. Skeletochronological age estimates for Hawaiian green turtles. Mar. Turtle Newsl. 33:9-10.

Table 1.--Summary of field studies.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted)	
			Total	Recoveries
		Kawela Bay, Oahu		
22 Feb.	2	Diurnal observational surveys from shore and interviews with local residents.	--	--
13 Mar.	2	Diurnal skin diving survey.	--	--
19 Mar.	2	Observational surveys from shore during predawn and morning hours.	--	--
26-28 Mar.	3	Nocturnal sampling with tangle nets set at the west end of the bay. Diurnal skin diving survey.	19	0
4 Apr.	3	Diurnal skin diving survey, including nearshore waters 1 km to the west of Kawela Bay.	--	--
8-9 Apr.	3	Nocturnal sampling with tangle nets set at the east end of the bay.	0	0
15-16 Apr.	3	Nocturnal sampling with tangle nets set at the west end of the bay. Blood samples collected. Diurnal skin diving survey.	6	1
14 June	3	Diurnal scuba surveys from an inflatable boat to a depth of 15.2 m (50 ft) involving 4 man-hours of bottom time.	--	--
25 June	3	Diurnal scuba surveys from an inflatable boat to a depth of 24.4 m (80 ft) involving 3.5 man-hours of bottom time. Stomach sample collected.	1	0
27-28 June	3	Nocturnal sampling with tangle nets set at the west end of the bay. Blood, bone biopsy, and stomach samples collected. Deep-body temperatures recorded. Diurnal skin diving survey.	5	0

Table 1.--Continued.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted)	
			Total	Recoveries
2-3 July	3	Nocturnal sampling with tangle nets set at the west end of the bay. Blood, bone biopsy, and stomach samples collected. Deep-body temperatures recorded. Diurnal skin diving survey.	5	0
15 Oct.	2	Observational surveys from shore during predawn and morning hours.	--	--
18 Oct.	2	Observational surveys from shore during predawn and morning hours.	--	--
20 Nov.	1	Observational surveys from shore during predawn and morning hours.	--	--
(20 days)		Subtotal	37	3
		Palaau, Molokai		
22-26 Apr.	2	Extensive sampling with bullpen net in cooperation with a local commercial fisherman. Blood and stomach samples collected. Diurnal skin diving surveys.	50	4
21-24 May	2	Diurnal scuba and skin diving surveys using an inflatable boat. Blood, bone biopsy, and stomach sample collected.	1	0
28 May-3 June	2	Diurnal skin diving and scuba surveys from shore and using an inflatable boat. Blood and stomach sample collected.	3	0
16-19 July	2	Extensive sampling with bullpen net in cooperation with a local commercial fisherman. Blood and stomach samples collected.	85	5
(20 days)		Subtotal	139	9

Table 1.--Continued.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted) Total	Recoveries
		Kahului Bay, Maui		
10-12 Apr.	2	Nocturnal census and observational studies from shore at warmwater outfall of the Maui Electric Plant. Diurnal skin diving survey.	--	--
1-10 May		Nocturnal census and observational studies from shore at warmwater outfall. One night of sampling with tangle nets. Bone biopsy and stomach sample collected. Nocturnal skin diving surveys. Diurnal scuba (to 19.8 m (65 ft)) and skin diving surveys using an inflatable boat.	1	0
17-21 June		Nocturnal sampling with tangle nets at warmwater outfall. Diurnal and nocturnal skin diving surveys. Nocturnal census and observational studies from shore. Bone biopsy, stomach, and blood samples collected. Deep-body temperatures recorded.	9	1
(20 days)		Subtotal	10	1
		Maunalua Bay, Oahu		
30 Apr.	3	Diurnal scuba surveys to a depth of 7.6 m (25 ft) involving 3 man-hours of bottom time. Stomach sample collected.	1	0
15 May	3	Diurnal scuba surveys to a depth of 10.7 m (35 ft) involving 3 man-hours of bottom time. Blood, bone biopsy, and stomach samples collected.	2	0

Table 1.--Continued.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted)	
			Total	Recoveries
		West Beach, Oahu		
12 Mar.	3	Diurnal observational surveys from shore.	--	--
20 Mar.	3	Observational surveys from shore during predawn and morning hours.	--	--
2 Apr.	3	Observational surveys from shore during predawn and morning hours. Diurnal skin diving survey.	--	--
24 Apr.	1	Observational surveys from shore during late afternoon and sunset periods.	--	--
11 June	1	Brief aerial survey and photography.	--	--
8 Aug.	4	Diurnal scuba surveys to a depth of 18.3 m (60 ft) involving 3.2 man-hours of bottom time.	--	--
		Sandy Beach, Oahu		
16 May	3	Diurnal observational surveys from shore.	--	--
		Honokowai, Maui		
11 Apr.	2	Observational surveys from shore during early morning hours. Diurnal skin diving surveys.	--	--
2 May	3	Diurnal scuba survey from an inflatable boat to a depth of 7.6 m (25 ft) involving 1 man-hour of bottom time.	--	--
10 May	3	Diurnal scuba surveys from an inflatable boat to a depth of 12.2 m (40 ft) involving 2 man-hours of bottom time.	--	--

Table 1.--Continued.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted) Total	Recoveries
		Maliko Bay, Maui		
12 Apr.	2	Diurnal skin diving survey from shore.	--	--
3 May	3	Diurnal scuba survey from an inflatable boat to a depth of 19.8 m (65 ft) involving 1.5 man-hours of bottom time.	--	--
		Olowalu, Maui		
8 May	3	Diurnal scuba surveys from an inflatable boat to a depth of 15.2 m (50 ft) involving 3 man-hours of bottom time.	--	--
		Keomuku, Lanai		
4 May	3	Diurnal scuba surveys from an inflatable boat to a depth of 18.3 m (60 ft) involving 3 man-hours of bottom time. Skin diving surveys. Stomach sample collected. Ocean access from Maui.	1	0
6 May	3	Diurnal scuba surveys from an inflatable boat to a depth of 16.8 m (55 ft) involving 4 man-hours of bottom time. Skin diving surveys. Stomach sample collected. Ocean access from Maui.	3	0
		Subtotal	4	0
		Kuahua, Lanai		
10-12 July	2	Diurnal skin diving surveys. Observational studies, census and hand capture of turtles foraging at the shoreline. Stomach samples collected.	2	0

Table 1.--Continued.

Date 1985	No. of personnel	Activity	No. of turtles captured (when attempted): Total	Recoveries
		Polihua, Lanai		
8-10 July	2	Nocturnal surveys of a mile-long sand beach to determine level of nesting activity. Diurnal observational surveys of coastal waters.	--	--
		Total	195	13

Table 2.--Results of turtle netting effort at Kawela Bay, Oahu.

Field study date 1985	Duration in hours	Length of nets (m)	Netting effort (meter-hours)	No. of turtles captured	Meter-hours per turtle
26-28 March	40	60	2,400	19	126
8-9 April[1]	5	18	90	0	--
15-16 April	15	36	540	[2]6	90
27-28 June	12	36	432	5	86
2-3 July	12	36	432	[3]6	72
Overall	84	--	3,894	36	108

[1]Net set at the east side of the bay. All other netting effort conducted at the west side of the bay.

[2]Includes one recapture.

[3]Includes two recaptures, one of which had already been recaptured on 15 April 1985.

Table 3.--Summary of samples collected from green turtles on Oahu, Molokai, Maui, and Lanai.

Location	Blood serum	Whole blood	Food samples	Bone and lamina biopsies
Kawela Bay, Oahu	13	11	13	3
Maunalua Bay, Oahu	2	--	1	2
Palaau, Molokai	36	26	21	1
Kahului Bay, Maui	1	--	7	6
Keomuku, Lanai	--	--	4	--
Kuahua, Lanai	--	--	2	--
Total	52	37	48	12

Table 4.--Biometrics of 34 green turtles sampled at Kawela Bay, Oahu.

Tag No.	Carapace length Straight (cm)	Carapace length Curved (cm)	Carapace width Straight (cm)	Carapace width Curved (cm)	Plastron length (cm)	Tail length (cm)	Head width (cm)	[1]Front flipper width (cm)
8773-74	38.7	40.5	34.3	40.0	31.1	8.5	6.4	7.0
8804-05	40.4	42.5	34.5	41.5	32.3	6.0	6.7	6.7
8493-94	40.8	43.9	34.0	39.5	33.0	7.5	6.9	7.9
8489-90	42.5	44.5	33.1	39.8	33.5	9.5	6.6	7.4
8508-09	43.4	45.5	33.8	39.0	34.6	7.2	7.3	7.2
8753-54	44.0	46.0	35.7	41.2	35.5	7.5	6.9	7.8
8495-96	44.9	47.0	36.8	42.5	35.9	8.0	7.8	8.0
8497-98	47.6	50.2	37.9	45.6	37.8	10.0	7.8	8.0
8751-52	49.9	52.5	40.7	47.2	40.1	7.0	8.2	8.6
8510-11	50.2	53.0	40.2	47.1	40.4	9.5	7.8	8.8
8512-13	52.9	56.5	40.1	48.5	41.7	8.5	8.1	8.7
8784-85	53.1	56.0	44.2	51.5	43.8	9.0	8.2	8.6
8801-03	54.0	58.0	39.9	49.5	43.1	9.5	8.5	9.1
8778-80	54.4	57.5	44.9	53.2	44.6	11.0	9.2	10.5
Not tagged	55.5	59.0	44.0	52.0	44.3	10.5	10.5	--
8757-58	55.9	59.5	43.2	53.0	45.4	12.5	8.6	9.5
8755-56	56.4	61.5	45.2	55.2	46.1	10.5	9.0	9.7
8759-60	59.6	62.5	48.6	59.0	48.0	14.0	9.6	10.4
8499-8500	60.9	65.0	46.6	56.5	47.9	14.0	9.0	10.0
8806-08	61.9	65.5	48.2	58.2	48.3	11.5	9.2	10.8
8761-63, 8505	64.0	68.5	52.0	63.0	50.9	14.0	9.5	10.6
8798-8800	65.7	70.5	50.2	62.0	53.7	11.0	9.8	--
8995-97	66.3	70.5	51.7	67.0	54.2	14.0	10.1	11.4
8770-72	66.3	70.0	52.3	65.5	55.4	16.0	10.6	11.7
8506-07	67.0	70.9	52.8	65.1	52.9	13.0	10.0	11.2
8786-88	67.0	71.5	54.0	66.5	55.0	13.0	10.3	11.9
8775-77	67.5	71.5	52.1	65.5	53.1	14.0	10.4	11.6
8809-11	67.6	72.5	53.3	68.0	55.3	13.5	10.2	11.3
8502-04	67.7	73.0	54.7	66.5	56.2	12.5	10.0	10.4
8764-66	69.0	72.5	54.5	69.0	57.6	16.0	10.7	--
8989-91	69.7	75.0	53.5	68.0	55.2	15.5	10.6	12.2
8781-83	72.0	75.5	55.4	69.0	57.0	16.5	10.7	12.3
8992-94	74.7	79.8	56.1	72.2	61.8	18.5	11.0	12.1
8767-69	75.1	81.0	61.2	76.0	59.8	14.5	11.4	12.7

[1]Straight-line measurement taken from the anterior distal edge of the claw scale to the scale located directly across on the flipper's trailing edge (usually scale No. 6 counting proximal to distal along the trailing edge).

Table 5.--Straight carapace lengths and curved/straight width ratios of 34 green turtles sampled at Kawela Bay, Oahu.

Tag No.	Straight carapace length (cm): Midline to posterior edge of the postcentrals	Straight carapace length (cm): Midline to notch	Straight carapace length (cm): Percent of posterior edge measurement	Carapace width: Curved/ straight ratio
8773-74	38.7	38.0	98.2	1.17
8804-05	40.4	39.6	98.0	1.20
8493-94	40.8	40.4	99.0	1.16
8489-90	42.5	42.3	99.5	1.20
8508-09	43.4	43.0	99.1	1.15
8753-54	44.0	43.8	99.5	1.15
8495-96	44.9	44.7	99.6	1.15
8497-98	47.6	47.4	99.6	1.20
8751-52	49.9	49.5	99.2	1.16
8510-11	50.2	50.0	99.6	1.17
8512-13	52.9	52.5	99.2	1.21
8784-85	53.1	52.7	99.2	1.15
8801-03	54.0	--	--	1.24
8778-80	54.4	54.2	99.6	1.18
Not tagged	55.5	55.1	99.3	1.18
8757-58	55.9	55.5	99.3	1.23
8755-56	56.4	56.4	100	1.22
8759-60	59.6	59.2	99.3	1.21
8499-8500	60.9	60.6	99.5	1.22
8806-08	61.9	61.6	99.5	1.21
8761-63, 8505	64.0	63.4	99.1	1.21
8798-8800	65.7	65.1	99.1	1.24
8770-72	66.3	65.6	98.9	1.25
8995-97	66.3	66.2	99.8	1.30
8506-07	67.0	66.9	99.9	1.23
8786-88	67.0	66.2	98.8	1.23
8775-77	67.5	67.0	99.3	1.26
8809-11	67.6	--	--	1.28
8502-04	67.7	67.3	99.4	1.22
8764-66	69.0	68.6	99.4	1.27
8989-91	69.7	69.4	99.6	1.27
8781-83	72.0	71.5	99.3	1.25
8992-94	74.7	74.6	99.9	1.29
8767-69	75.1	74.7	99.5	1.24

Table 6.--Carapace lengths and weights for 20 green turtles sampled on Oahu and Molokai.

Tag No.	Straight carapace length (cm)	Curved carapace length (cm)	Weight (kg)	(lb)
		Kawela Bay, Oahu		
8804-05	40.4	42.5	10.9	24
8801-03	54.0	58.0	20.9	46
8806-08	61.9	65.5	34.5	76
8761-63, 8505	64.1	--	35.5	78
8798-8800	65.7	70.5	37.3	82
8809-11	67.6	72.5	41.4	91
		Palaau, Molokai		
8539-40	38.8	40.5	7.3	16
8541-42	38.8	41.5	8.6	19
7825-26	39.6	41.5	8.6	19
7829-30	46.7	50.0	14.1	31
7831-32	49.3	52.5	19.5	43
8543-44	51.8	56.0	19.5	43
8549-50	52.1	55.5	19.5	43
8545-46	52.2	56.0	20.9	46
7893-94	51.9	56.0	19.5	43
7827-28	53.0	56.5	20.9	46
8547-48	53.6	58.5	22.3	49
8627-28	55.8	59.5	25.0	55
7798-99	62.9	68.5	31.8	70
7833-34	63.4	67.5	34.5	76

Table 7.--Identification of stomach contents sampled from 12 green turtles at Kawela Bay, Oahu.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
8493-94	40.8	Laurencia mariannensis	99
		Jania capillacea	T
		Acanthophora spicifera	T
		Polysiphonia horvei	T
		Oscillatoria sp.	T
8489-90[1]	42.5	Amansia glomerata	50
		Codium edule	25
		Pterocladia sp.	5
		Ceramium sp.	T
		Ralfsia occidentalis	T
8508-09	43.4	Acanthophora spicifera	99
		L. nidifica	T
		Amansia glomerata	T
		Hypnea pannosa	T
		Gelidium sp.	T
8495-96	44.9	Acanthophora spicifera	99
		Codium edule	1
		Oscillatoria sp.	T
8497-98	47.6	A. spicifera	99
		L. nidifica	1
		Terrestrial plant material	T
8510-11	50.2	A. spicifera	99
		J. capillacea	T
		Amansia glomerata	T
		Corallina sp.	T
8512-13	52.9	Acanthophora spicifera	99
		Laurencia nidifica	1
8778-80	54.6	A. spicifera	99
		Microdictyon sp.	T
		Polysiphonia sp.	T
8499-8501	60.9	A. spicifera	99
		Ceramium sp.	T
		Laurencia sp.	T
		Dictyota acuteloba	T
8761,8763, 8505	64.5	Amansia glomerata	99
		Laurencia sp.	1
		Ulva reticulata	T
8506-07	67.0	Acanthophora spicifera	99
		D. acuteloba	T
		Amansia glomerata	T
		U. rericulata	T
8502-04	67.7	Acanthophora spicifera	100

[1]Captured by hand on 25 June 1985 during scuba surveys of resting habitat outside of Kawela Bay.

Table 8.--Identification of stomach contents from a green turtle found dead at Kawela Bay, Oahu, on 28 March 1985.

Carapace length		Carapace width		Plastron length (cm)	Tail length (cm)	Head width (cm)
Straight (cm)	Curved (cm)	Straight (cm)	Curved (cm)			
55.5	59.0	44.0	52.0	44.3	10.5	10.5

Benthic algae	Approximate (%)
Ulva reticulata Forsskal	75
Pterocladia capillacea (Gmelin) Bornet	20
Amansia glomerata C. Ag.	2
Turbinaria ornata J. Ag.	2
Rhodophyta (red)	
Acanthophora spicifera (Vahl) Boerg.	Trace
Botryocladia skottsbergii (Boerg.) Levr.	Trace
Gelidiopsis variable J. Ag.	Trace
Griffithsia tenuis C. Ag.	Trace
Hypnea musciformis (Wulfen) C. Ag.	Trace
Laurencia cartilaginea Yamada	Trace
Leveillea jungermannioides Harv.	Trace
Martensia fragilis Harv.	Trace
Chlorophyta (green)	
Cladophoropsis gracillum Dau	Trace
Codium arabicum Kutzing	Trace
C. edule Silva	Trace
Phaeophyta (brown)	
Sargassum polyphyllum J. Ag.	Trace
Invertebrates	
Porifera	
Chondrosia chucalla	

Table 9.--Epizoites sampled from four green turtles on Oahu, Molokai, and Maui.

Tag No.	Straight carapace length (cm)	Location	Epizoites
8495-96	44.9	Kawela Bay, Oahu	Sphacelaria tribuloides Polysiphonia tsudana Melobesia sp. Platylepas hexastylos (harmless skin barnacle) Small clawed shrimp larva
8545-46	52.2	Palaau, Molokai	S. tribuloides P. scropulorum Lyngbya semiplena
7917-18	57.4	Palaau, Molokai	S. furcigera P. tsudana P. setacea Pilinia rimosa Calothrix sp. Melobesia sp. Platylepas hexastylos
8479-81[1]	71.8	Kahului Bay, Maui	Chaetomorpha brachygona Melobesia sp. Polysiphonia sp. Platylepas hexastylos

[1]The burrowing barnacle, Stephanolepas muricata, was found along the anterior edge of the front flippers on six of the other turtles captured at this site. In addition, two turtles caught here had several Chelonibia testudinaria on their carapace and plastron. This nonburrowing, harmless barnacle is commonly found on green turtles at some locations in Hawaii, but not at the principal study sites covered in this report.

Table 10.--Injuries and abnormalities found on six green turtles at Kawela Bay, Oahu. (See also Table 11.)

Tag No.	Straight carapace length (cm)	Description
8508-09	43.4	Left third lateral scute of carapace partly lifted up and peeling.
8784-85	53.1	Monofilament fishing line protruding from the cloaca; manually removed with no apparent injury.
8506	67.0	Moderately deep scratch in left side of carapace through the second and third lateral scutes.
8809-11	67.6	Healed piece missing from left posterior edge of the carapace between the 10th marginal scute and the postcentrals. Approximately 20% of right hind flipper missing but healed.
8764-66	69.0	Small neoplasms in the posterior corner of each eye.
8781-83	72.0	Healed indentation in the second right lateral scute.

Table 11.--Histology report by Grant N. Stemmermann, M.D.,[1] for a green turtle found dead at Kawela Bay, Oahu, on 28 March 1985.

Lungs:	There is marked enlargement of the alveolar spaces, associated with greatly increased amounts of smooth muscle in the alveolar walls. The alveolar septa contain numerous embryonated helminth eggs, most of which are surrounded by multinucleated histiocytes. The pulmonary arteries, especially the large and medium-sized vessels, show extensive intimal thickening by smooth muscle. This almost obliterates the lumens of some vessels.
Liver:	The lobular architecture is fairly well preserved, although there are large numbers of hemosiderin-laden histiocytes through all portions of the lobules. Ova similar to those in the lungs are found within the lobules, but are fewer in number and are associated with a less conspicuous host reaction. A single, fairly large segment of the portal vein has a markedly thickened intima and is surrounded by clusters of round cells.
Small intestine:	There is too much autolysis to distinguish much cytologic or even histologic detail in the mucosa. However, the configuration of the villi suggest that there has been marked mucosal damage and inflammation, associated with the accumulation of many round cells in the lamina propria. The mucosa and submucosa contain occasional helminth ova. They are larger than those in the liver and lungs.
Kidney:	The configuration of the glomeruli, some in the process of subcapsular development, suggest that this animal is not yet mature. Present in both the capsule and the interstitium of the cortex are occasional ova similar to those in the liver and lung. The renal artery is markedly thickened in its intimal aspects and also shows distinct endothelial hyperplasia. There is a single glomerulus that shows cellular infiltration, adhesions between capillary and capsule, and basement membrane thickening. This glomerulus is surrounded by a dense cuff of round cells. There is one embryonated ovum within a distal convoluted tubule. This egg is not associated with either cell reaction or tubular damage.
Conclusions:	This animal apparently succumbed to the effect of cardiovascular fluke infection (Digenea: Spirorchidae). The most extensive tissue damage was found in the lungs, which showed extensive interstitial fibrosis and severe pulmonary sclerosis consistent with debilitating right heart failure; and of the small gut where there was extensive mucosal necrosis and ulceration. The latter would have been inconsistent with adequate nutrition. Renal involvement was associated with focal embolic glomerulonephritis. The presence of embryonated eggs in undamaged distal convoluted tubules suggests that some eggs may be passed in the urine.

[1]Address: 46-458 Haiku Plantation Drive, Kaneohe, HI 96744.

Table 12.--Growth rates of two green turtles recaptured at Kawela Bay, Oahu.

Tag No.	1985 Date tagged Date recaptured	Carapace length (cm)		Recovery interval (months)	Growth rate in cm/month		Growth rate in cm/year	
		Straight	Curved		Straight	Curved	Straight	Curved
8761-63	3/26 4/15 7/3	64.0	68.5	3.2	0.16	0.37	1.87	4.50
8778-80	3/27 7/3	54.4	57.5	3.2	0.06	0.31	0.75	3.75
Mean growth rates					0.11	0.34	1.31	4.12

Table 13.--Deep-body temperatures of nine green turtles sampled at Kawela Bay, Oahu, and Kahului Bay, Maui.

Tag No.	Straight carapace length (cm)	Date 1985	Approximate time of capture	Deep body temperature (°C)
		Kawela Bay, Oahu		
8502-04	67.7	28 June	0030	26.7
8499-8500	60.9	28 June	0200	26.2
8497-98	47.6	28 June	0430	25.6
8495-96	44.9	28 June	0630	24.8
8761, 8763, 8505	64.9	2 July	2200	25.9
8506-07	67.0	3 July	0100	26.3
8510-11	50.2	3 July	0230	24.8
		Kahului Bay, Maui		
8468-71	92.0	18 June	2230	28.8
8479-81	71.8	19 June	0030	27.6

Ambient temperature on the west side of Kawela Bay at high tide was 26.5°-27.5°C. At low tide (0530-0700) it was 23°-24°C due to the greater influence of freshwater discharge from the spring.

Temperature in the outfall plume where the turtles were captured was 30°C. Farther from shore beyond the direct influence of the outfall the ambient temperature was 26.5°C.

Table 14.--Results of bullpen netting effort for green turtles at Palaau, Molokai.

Field study date 1985	Netting location	Duration in hours	Number of turtles captured	[1]Meter-hours per turtle
22-23 April	A	15	[2]8	1,125
23-24 April	B	18	[3]23	470
24-25 April	B	20	[4]16	750
25-26 April	C	20	3	4,000
15-16 July	D	19	10	1,140
16-17 July	E	20	[4,5]24	500
17-18 July	E	21	[5,6]12	1,050
18-19 July	F	20	[4,7]39	308
Overall		153	135	680

[1]Approximate net length 600 m.

[2]Includes three recaptures of turtles tagged at Palaau prior to this study.

[3]Includes the short-term recapture of a turtle tagged by the commercial fisherman on 11 April 1985.

[4]At least two other turtles are known to have escaped from the net enclosure.

[5]Includes two recaptures of turtles tagged during 22-26 April 1985.

[6]Includes a short-term recapture originally tagged on 16-17 July 1985.

[7]Includes the short-term recapture of a turtle tagged by the commercial fishermen on 11 July 1985.

Table 15.--Biometrics of 133 green turtles sampled at Palaau, Molokai. (A, B, C, D, E, F = netting sites; B2, E2 = second consecutive night at netting sites B and E; H = hand capture.)

Tag No.	Site	Carapace length Straight (cm)	Carapace length Curved (cm)	Carapace width Straight (cm)	Carapace width Curved (cm)	Plastron length (cm)	Tail length (cm)	Head width (cm)	Front flipper width (cm)
9423-24	F	38.2	41.0	32.4	38.0	--	--	6.4	7.0
8539-40	E	38.8	40.5	32.9	36.5	31.4	6.8	6.0	7.1
8541-42	E	38.8	41.5	32.8	38.5	29.9	6.0	6.1	6.6
7945-46	A	38.8	41.0	31.4	37.2	31.2	5.5	6.5	7.1
7825-26	E2	39.6	41.5	33.2	38.0	32.0	6.5	6.6	7.1
7902-03	A	39.7	42.0	34.4	40.0	32.0	8.0	6.5	6.9
8521-22	D	39.7	42.5	32.5	38.5	32.3	6.5	6.4	7.3
8580-8581	B	39.9	--	34.6	--	32.6	--	6.1	6.9
9462-63	F	40.2	42.0	33.6	38.5	--	--	6.5	7.3
8601,8650	C	40.6	43.0	34.5	41.0	32.0	7.0	6.6	6.8
9419-20	F	40.9	42.5	33.7	39.0	--	--	6.9	7.1
8458-59	H	41.2	43.3	33.9	40.7	31.8	8.5	6.7	7.3
9458-59	F	41.3	44.0	33.8	40.0	--	--	6.9	7.3
9417-18	F	41.5	44.0	35.0	40.5	--	--	6.5	7.1
7901,7905	A	41.6	44.5	32.6	39.7	34.3	7.5	6.5	6.7
9456-57	F	42.5	45.0	35.0	40.0	--	--	6.7	7.1
8600,8626	B2	42.7	45.5	34.6	41.0	34.6	9.0	7.2	7.9
9452-53	F	42.9	46.0	34.4	41.0	--	--	7.0	7.5
9460-61	F	43.0	46.0	34.0	40.5	--	--	7.1	7.2
8460-61	H	--	46.0	--	44.5	--	--	--	--
9415-16	F	43.1	46.0	35.8	42.0	--	--	6.9	--
7303-04	A	43.7	46.5	35.1	41.3	35.9	9.0	7.4	7.9
9464-65	F	43.8	46.5	37.9	43.5	--	--	7.0	7.6
9421-22	F	44.1	46.0	36.4	41.0	--	--	7.3	7.9
8523-24	D	44.3	46.5	35.4	41.5	35.4	7.0	7.3	7.5
7301-02	A	44.4	47.0	34.5	40.0	35.4	9.0	7.0	--
8525-26	D	44.7	48.5	36.2	43.0	35.0	6.5	7.2	7.5
9454-55	F	44.8	48.0	35.2	41.5	--	--	7.3	7.8
9450-51	F	45.1	48.0	36.4	43.0	--	--	7.4	7.6
7919-20	B	45.5	48.5	35.8	43.5	35.9	9.0	7.6	7.9
7915-16	B	45.6	48.5	37.8	45.0	37.6	9.0	8.9	7.9
9448-49	F	46.5	49.5	37.2	44.0	--	--	7.6	8.1
8529-30	D	46.5	49.5	38.8	46.0	37.6	7.8	9.0	8.3
7829-30	E2	46.7	50.0	37.0	42.5	36.5	9.5	7.2	7.9
8575-76	B	47.0	50.0	39.9	47.0	39.0	8.0	7.9	8.1
7913-14	B	47.4	50.7	38.7	45.8	39.4	10.5	7.5	8.2
7794-95	E	47.4	50.0	38.6	44.5	38.8	8.0	7.3	--
9444-45	F	47.4	51.0	38.2	43.5	--	--	7.5	8.2
8638-39	B2	47.5	50.5	37.0	44.5	37.4	9.0	7.8	8.7
9446-47	F	47.8	51.0	37.8	45.5	--	--	7.6	7.6
7924-25	B	48.0	50.5	37.3	44.3	--	--	7.7	8.1
9436-37	F	48.5	52.0	39.7	48.0	--	--	8.0	8.2
7882-83	B	48.8	52.6	37.5	46.2	40.2	8.0	7.8	8.5
9442-43	F	48.8	51.5	38.0	45.5	--	--	7.0	8.6
8527-28	D	48.8	52.0	38.3	44.5	38.6	--	7.9	8.1

Table 15.--Continued.

Tag No.	Site	Carapace length Straight (cm)	Carapace length Curved (cm)	Carapace width Straight (cm)	Carapace width Curved (cm)	Plastron length (cm)	Tail length (cm)	Head width (cm)	Front flipper width (cm)
8519-20	D	49.0	53.0	38.0	45.5	37.9	--	7.4	8.1
8640-41	B2	49.2	53.0	39.7	46.0	39.6	8.0	8.1	8.8
8462-63	H	--	53.3	--	46.0	--	--	--	--
7831-32	E2	49.3	52.5	40.3	49.5	39.7	11.0	7.9	9.1
8642-43	B2	49.7	54.0	38.6	47.0	41.1	9.5	7.8	8.8
9413-14	F	50.0	53.5	40.4	47.0	--	--	8.1	--
7842-43	E2	50.2	53.5	39.1	46.5	--	--	7.8	8.3
8636-37	B2	51.3	56.5	41.1	48.0	41.4	8.0	8.2	9.6
7893-94	B	51.5	55.5	39.4	48.5	41.4	10.0	8.4	9.0
7947-49	A	51.7	55.2	40.2	48.3	41.1	9.5	8.3	8.8
8543-44	E	51.8	56.0	41.3	49.5	41.7	8.5	8.0	9.1
9433-34	F	52.0	55.5	40.7	47.5	--	--	8.0	8.8
8549-50	E	52.1	55.5	39.4	47.5	43.3	9.0	8.2	--
8545-46	E	52.2	56.0	40.7	48.5	41.1	8.5	8.2	9.1
9435	F	52.3	56.0	40.9	47.5	--	--	7.6	8.2
7804-05	E	52.8	56.5	41.1	49.0	43.9	9.0	8.6	8.8
7792-93	E	52.9	55.5	40.3	47.0	42.4	11.5	8.3	9.1
7827-28	E2	53.0	56.5	40.7	47.0	42.7	9.5	8.5	8.8
9438-39	F	53.4	57.5	41.0	49.5	--	--	8.2	8.5
8547-48	E	53.6	58.5	41.6	51.5	43.9	9.5	8.7	9.2
8537-38	D	54.7	58.0	42.0	50.0	45.4	13.0	8.7	6.6
8632-33	B2	55.0	59.0	43.5	52.5	44.8	10.5	8.4	9.8
8627-28	B2	55.3	59.0	41.3	50.8	43.6	10.0	8.7	9.2
9427-28	F	55.5	59.5	42.4	52.0	--	--	8.6	9.6
7802-03	E	55.6	59.0	44.8	52.5	44.3	12.5	8.4	9.5
9407-08	F	55.8	59.0	45.3	54.0	--	--	8.5	9.5
9440-41	F	55.9	59.5	44.0	52.0	--	--	8.7	9.9
9405-06	F	56.0	61.0	44.4	52.5	--	--	8.5	9.4
9409-10	F	56.4	60.5	43.9	52.5	--	--	8.5	9.7
9431-32	F	56.4	60.5	43.5	51.0	--	--	8.3	9.0
7907-09	B	56.7	60.8	45.0	55.5	45.8	12.0	9.0	9.2
9429-30	F	56.9	61.0	44.2	51.0	--	--	8.6	9.5
7917-18	B	57.2	60.6	46.7	55.3	46.7	10.5	8.9	9.7
8629-31	B2	57.3	61.0	45.2	55.5	47.0	--	9.1	9.6
8634-35	B2	57.8	62.0	45.1	52.5	47.1	11.6	9.1	9.5
7796-97	E	57.9	62.0	45.3	54.5	46.1	--	8.7	9.4
8531-32	D	58.7	63.0	44.0	52.5	46.8	12.0	9.0	10.8
7748,7801	E	59.4	63.0	45.9	55.0	47.5	11.0	9.0	9.8
7879-81	B	59.4	63.5	46.0	56.0	48.9	11.5	9.1	10.4
7939-40	B2	59.5	64.5	46.9	56.5	46.2	12.0	9.3	10.3
9425-26	F	60.0	--	47.2	56.0	--	--	8.9	9.5
7887-89	B	60.0	64.5	49.3	58.0	49.0	11.0	9.2	10.9
8453-55	H	60.2	64.5	48.4	58.5	48.3	14.0	9.4	10.6
8597-99	B2	61.5	66.0	50.8	61.5	49.9	11.0	9.6	10.8

Table 15.--Continued.

Tag No.	Site	Carapace length Straight (cm)	Carapace length Curved (cm)	Carapace width Straight (cm)	Carapace width Curved (cm)	Plastron length (cm)	Tail length (cm)	Head width (cm)	Front flipper width (cm)
8577-79	B	61.7	66.2	48.7	60.0	49.0	12.5	8.8	9.8
8591-93	B2	61.9	67.0	49.4	61.0	49.7	10.5	9.8	10.5
7910-12	B	61.9	66.4	49.1	59.0	49.6	12.5	9.7	10.2
9403-04	F	62.0	67.0	51.3	60.5	--	--	9.1	9.8
8535-36	D	62.0	66.5	48.3	59.0	48.9	14.5	9.1	10.6
7798-99	E	62.9	68.5	47.0	56.0	51.3	12.0	9.5	10.5
6376-77	A	63.3	68.0	52.4	64.0	50.3	10.5	9.9	12.6
7833-34	E2	63.4	67.5	50.4	60.0	50.9	13.0	9.5	11.1
7819-20	E	63.7	68.0	48.0	58.5	--	--	9.2	10.4
8594-96	B2	63.8	69.0	50.6	63.5	51.0	11.5	9.3	9.7
7895-97	B	63.8	68.0	50.0	61.5	51.3	13.0	9.6	10.3
8569-71	B	63.9	68.7	49.8	62.0	52.3	14.0	10.0	10.9
7812-14	E	64.6	69.5	50.3	60.5	--	--	10.3	11.4
7942-44	A	65.0	69.5	50.2	61.0	52.1	12.0	9.6	10.4
8533-34	D	65.1	69.0	--	--	52.8	16.0	9.6	11.0
7823-24	E	65.5	70.0	52.2	61.0	--	--	9.7	10.8
7890-92	B	65.8	71.0	51.3	61.0	52.2	15.0	9.2	10.4
7846-47	F	66.3	70.5	51.0	63.0	--	--	9.7	10.8
7815-16	E	66.3	72.0	54.1	65.5	--	--	9.9	10.9
7876-78	B	66.4	70.5	53.7	63.5	53.3	16.0	9.5	10.4
9466-67	F	66.9	70.5	51.3	65.0	54.2	--	10.3	12.0
8847-48	F	67.0	71.0	52.6	64.5	--	--	9.9	11.8
8644-46	C	67.3	72.5	54.0	65.0	54.6	12.5	9.8	10.7
9411-12	F	67.4	72.5	52.4	66.5	--	--	9.6	11.3
7835-36	E2	68.6	73.5	--	64.5	55.0	16.0	10.0	12.1
7821-22	E	69.7	76.0	53.7	68.0	--	--	10.6	11.1
7898-7900	B	69.8	75.0	57.0	69.0	58.8	12.5	10.7	12.3
7817-18	E	70.3	75.5	59.4	69.5	--	--	10.0	10.2
7884-86	B	70.6	76.5	54.5	68.0	57.5	14.5	9.9	11.4
8588-90	B2	70.7	75.0	53.2	66.5	56.9	16.0	10.0	11.5
7810-11	E	70.8	76.0	57.4	70.0	--	--	10.2	12.0
8585-87	B2	70.9	76.0	--	68.0	57.3	15.5	10.6	12.1
7921-23	B	71.0	78.0	56.3	71.3	56.2	14.5	10.5	12.3
8647-49	C	71.4	77.5	56.6	71.4	56.1	18.0	9.6	11.5
7837-38	E2	71.8	78.0	--	69.0	--	--	10.4	12.3
7808-09	E	73.3	79.0	59.2	71.5	--	--	10.8	--
8572-74	B	74.0	78.5	58.8	68.5	59.5	17.5	10.6	13.6
7904-06	B	74.0	79.0	58.0	72.8	58.9	17.0	10.6	11.4
7806-07	E	75.9	80.5	56.9	74.0	--	--	--	--
7844-45	F	76.0	81.5	60.0	77.0	--	--	11.0	12.6
9401-02	F	77.5	82.0	59.5	74.0	--	--	10.8	12.5
7848-50	F	78.6	83.5	59.1	71.5	--	--	10.8	13.5
8582-84	B2	79.2	85.3	60.3	77.0	64.3	21.5	10.9	13.0
7839-41	E2	79.4	85.5	61.7	78.0	--	--	11.4	13.4

Table 16.--Straight carapace lengths and curved/straight width ratios of 128 green turtles sampled at Palaau, Molokai.

Tag No.	Straight carapace length (cm) Midline to posterior edge of the postcentrals	Midline to notch	Percent of posterior edge measurement	Carapace width Curved and straight ratio
9423-24	38.2	37.9	99.2	1.17
8541-42	38.8	38.2	98.4	1.17
7945-46	38.8	38.4	99.0	1.18
8539-40	38.8	38.1	98.2	1.11
7825-26	39.6	39.1	98.7	1.14
8521-22	39.7	39.4	99.2	1.18
7902-03	39.7	39.0	98.2	1.16
8580-81	39.9	39.2	98.2	--
9462-63	40.2	39.7	98.8	1.15
8601, 8650	40.6	40.2	99.0	1.19
9419-20	40.9	40.1	98.0	1.16
8458-59	41.2	40.6	98.5	1.20
9458-59	41.3	40.8	98.8	1.18
9417-18	41.5	40.6	97.8	1.16
7901, 7950	41.6	41.1	98.8	1.22
9456-57	42.5	42.0	98.8	1.14
8600, 8626	42.7	42.5	99.5	1.18
9452-53	42.9	42.5	99.1	1.19
9460-61	43.0	42.7	99.3	1.19
9415-16	43.6	43.6	100	1.17
9464-65	43.8	43.1	98.4	1.15
9421-22	44.1	43.8	99.3	1.13
8523-24	44.3	44.0	99.3	1.17
8525-26	44.7	44.4	99.3	1.19
9454-55	44.8	44.4	99.1	1.18
9450-51	45.1	44.9	99.6	1.18
7919-20	45.5	45.1	99.1	1.22
7915-16	45.6	45.1	98.9	1.19
9448-49	46.5	46.2	99.3	1.18
8529-30	46.5	46.2	99.4	1.19
7829-30	46.7	46.4	99.4	1.15
8575-76	47.0	46.6	99.1	1.18
7913-14	47.4	47.2	99.6	1.18
9444-45	47.4	47.2	99.6	1.14
7794-95	47.4	47.1	99.4	1.15
8638-39	47.5	47.2	99.3	1.20
9446-47	47.8	47.5	99.4	1.20
7924-25	48.0	47.6	99.1	1.19
9442-43	48.8	48.4	99.2	1.20
9436-37	48.5	48.2	99.4	1.21
8527-28	48.8	48.4	99.2	1.16
7882-83	48.8	48.5	99.4	1.23

Table 16.--Continued.

Tag No.	Straight carapace length (cm): Midline to posterior edge of the postcentrals	Midline to notch	Percent of posterior edge measurement	Carapace width: Curved and straight ratio
8519-20	49.0	48.5	99.0	1.20
8640-41	49.2	48.9	99.4	1.16
7831-32	49.3	49.0	99.4	1.23
8642-43	49.7	49.4	99.4	1.22
9413-14	50.0	49.5	99.0	1.16
7842-43	50.2	50.0	99.6	1.19
8636-37	51.3	50.9	99.2	1.17
7893-94	51.5	51.1	99.2	1.23
7947-49	51.7	51.3	99.2	1.20
8543-44	51.8	51.6	99.6	1.20
9433-34	52.0	51.7	99.4	1.16
8549-50	52.1	52.0	99.8	1.21
8545-46	52.2	52.1	99.8	1.19
9435	52.3	51.9	99.2	1.16
7804-05	52.8	52.6	99.6	1.19
7792-93	52.9	52.8	99.8	1.17
7827-28	53.0	52.8	99.6	1.15
9438-39	53.4	53.0	99.3	1.21
8547-48	53.6	53.2	99.3	1.24
8537-38	54.7	54.7	100	1.19
8632-33	55.0	54.5	99.1	1.21
862/-28	55.3	55.0	99.5	1.23
9427-28	55.5	55.0	99.1	1.23
7802-03	55.6	55.2	99.3	1.17
9407-08	55.8	55.6	99.6	1.19
9440-41	55.9	55.7	99.6	1.18
9405-06	56.0	55.7	99.5	1.18
9431-32	56.4	56.3	99.8	1.17
9409-10	56.4	56.0	99.3	1.20
7907-09	56.7	56.1	98.9	1.22
9429-30	56.9	56.4	99.1	1.15
7917-18	57.2	56.7	99.1	1.18
8629-31	57.3	57.2	99.8	1.23
8634-35	57.8	57.8	100	1.16
7796-97	57.9	57.3	99.0	1.20
8531-32	58.7	58.5	99.7	1.19
7748, 7801	59.4	59.1	99.5	1.20
7879-81	59.4	59.4	100	1.22
9425-26	60.0	59.6	99.3	1.19
7887-89	60.0	59.9	99.8	1.18
8453-55	60.2	--	--	1.21
8597-99	61.5	61.2	99.5	1.21
8577-79	61.7	61.6	99.8	1.23

Table 16.--Continued.

Tag No.	Straight carapace length (cm): Midline to posterior edge of the postcentrals	Straight carapace length (cm): Midline to notch	Straight carapace length (cm): Percent of posterior edge measurement	Carapace width: Curved and straight ratio
8591-93	61.9	61.7	99.7	1.23
7910-12	61.9	61.2	98.9	1.25
8535-36	62.0	61.6	99.4	1.22
9403-04	62.0	61.9	99.8	1.18
7798-99, 7800	62.9	62.5	99.4	1.19
6376-77, 7941	63.3	63.1	99.7	1.22
7833-34	63.4	63.3	99.8	1.19
7819-20	63.7	63.4	99.5	1.22
8594-96	63.8	63.0	98.7	1.25
7895-97	63.8	63.5	99.5	1.23
8569-71	63.9	63.7	99.7	1.24
7812-14	64.6	64.2	99.4	1.20
7942-44	65.0	64.8	99.7	1.22
8533-34	65.1	64.6	99.2	--
7823-24	65.5	65.0	99.2	1.17
7890-92	65.8	65.7	99.8	1.19
7846-47	66.3	66.3	100	1.24
7815-16	66.3	66.3	100	1.21
7876-78	66.4	66.2	99.7	1.18
9466-67	66.9	66.6	99.6	1.27
8644-46	67.3	66.7	99.1	1.20
9411-12	67.4	67.0	99.4	1.27
7835-36	68.6	68.4	99.7	--
7821-22	69.7	69.4	99.6	1.27
7878-7900	69.8	69.5	99.6	1.21
7817-18	70.3	70.0	99.6	1.17
7884-86	70.6	69.9	99.0	1.25
8588-90	70.7	70.3	99.4	1.25
7810-11	70.8	70.4	99.4	1.22
8585-87	70.9	70.6	99.6	--
7921-23	71.0	70.6	99.4	1.27
8647-48	71.4	71.0	99.4	1.26
7837-38	71.8	71.6	99.7	--
7808-09	73.3	73.3	100	1.21
8572-74	74.0	73.5	99.3	1.16
7904-06	74.0	73.9	99.9	1.26
7806-07	75.9	75.4	99.3	1.30
7844-45	76.0	75.8	99.7	1.28
9401-02	77.5	77.2	99.6	1.24
7848-50	78.6	78.4	99.7	1.21
8582-84	79.2	79.0	99.7	1.28
7839-41	79.4	79.0	99.5	1.26

Table 17.--Identification of stomach contents sampled from 21 green turtles at Palaau, Molokai.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
8539-40	38.8	*Acanthophora spicifera*	40
		Hypnea nidifica	40
		Amansia glomerata	20
		Halimeda discoidea	T
		Polysiphona sp.	T
		Spyridia filamentosa	T
		Hypneocolax stellaris	T
8541-42	38.8	*Hypnea cervicornis*	50
		Acanthophora spicifera	50
		Halophila hawaiiana	T
		Amansia glomerata	T
7825-26	39.6	*H. hawaiiana*	75
		A. glomerata	25
		Dictyota acuteloba	T
		Gelidium sp.	T
		Acanthophora spicifera	T
8580	39.9	*Amansia glomerata*	T
8601, 8650	40.6	*Acanthophora spicifera*	95
		D. friabilis	1
		Hypnea nidifica	1
		Dictyopteris sp.	1
		Laurencia nidifica	1
		Halophila hawaiiana	1
		Sargassum polyphyllum	T
		Jania capillacea	T
		Halimeda discoidea	T
		Amphipod	
8458-59	41.2	*Hypnea* sp.	T
		Laurencia sp.	T
		Codium edule	T
		Ocillatoria sp.	T
8600, 8626	42.7	*A. spicifera*	90
		H. cervicornis	10
		Halophilia hawaiiana	T

Table 17.--Continued.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
7829-30	46.7	A. spicifera	75
		Spyridia filamentosa	25
		Dictyota divaricata	T
		L. nidifica	T
		Ceramium sp.	T
		Polysiphonia sp.	T
		Sphacelaria sp.	T
		Amphipod	
8638-39	47.5	Acanthophora spicifera	99
		Hypnea cervicornis	T
		Spyridia filamentosa	T
		Polysiphonia pseudovillum	T
7831-32	49.3	Amansia glomerata	75
		Acanthophora spicifera	25
		L. nidifica	T
		D. divaricata	T
		Sphacelaria tribuloides	T
		Polysiphonia sp.	T
		H. cervicornis	T
8636-37	51.3	Spyridia filamentosa	99
		Ceramium sp.	T
		Small snail egg mass	
8543-44	51.8	Halophila hawaiiana	50
		S. filamentosa	30
		A. spicifera	20
		Lyngbya sp.	T
7893-94[1]	51.9	S. filamentosa	40
		A. spicifera	20
		L. nidifica	20
		H. cervicornis	20
		Centroceros clavulatum	T
		Sargassum polyphyllum	T
		Dictyota sp.	T
		Amphipods	
		Small snails	
8549-50	52.1	A. spicifera	95
		H. hawaiiana	2
		Amansia glomerata	2
		Hypnea cervicornis	1
		Ceramium sp.	T

Table 17.--Continued.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
7827-28	53.0	*Chondrococcus hornemanni*	99
		A. glomerata	T
		Acanthophora spicifera	T
		Amphipod	
8547-48	53.6	*Amansia glomerata*	95
		Gelidium sp.	5
		Halophila hawaiiana	T
		Ceramium sp.	T
		Acrochaetium sp.	T
		Sphacelaria sp.	T
		Amphipods	
8627-28[1]	55.8	*Acanthophora spicifera*	99
		Hypnea cervicornis	1
		Centroceros clavulatum	T
		Polysiphonia sp.	T
		Gelidiella sp.	T
8453-55	60.2	*Amansia glomerata*	99
		Ceramium sp.	T
		Hypnea sp.	T
		Polypiocladia calodictyon	T
		Amphipod	
7833-34	63.4	*Turbinaria ornata*	40
		A. glomerata	30
		Chondrococcus hornemanni	30
		Dictyopteris plogiograma	T
		Amphipods	
7835-36	68.6	*Spyridia filamentosa*	75
		Acanthophora spicifera	25
		Amansia glomerata	T
		Bryopsis pennata	T
		Valonia aegagropila	T
		Ceramium sp.	T
		L. majuscula	T
		Oscillatoria sp.	T
7921-23	71.3	*Acanthophora spicifera*	80
		S. filamentosa	15
		V. aegagropila	5
		Polysiphonia horvei	T
		Amphipods	

[1]Tag recaptures resulting in growth data. See Table 19.

Table 18.--Injuries and abnormalities found on 15 green turtles at Palaau, Molokai.

Tag No.	Straight carapace length (cm)	Description
9421-22	44.1	Healed slit between the 11th right marginal scute and postcentral.
7882-83	48.8	Healed indentation in first and second left lateral scutes.
7842-43	50.2	Large healed piece missing from the 10th and 11th right marginal scutes.
9435	52.3	Healed identation between the 11th right marginal scute and postcentral. A substantial portion of the trailing edge of the left front flipper missing but healed.
9409-10	56.4	Two healed gouges on the left side of the carapace. Photo taken.
8634-35	57.8	Healed piece missing from fourth right marginal scute.
7819-20	63.7	Partly healed puncture in second central scute, likely from spear penetration.
8533-34	65.1	Large healed indentation in sixth and seventh left lateral scutes. Also a missing healed strip from the third through 8th left marginal scutes.
7846-47	66.3	Deep partly healed lacerations to left hind flipper. Right postcentral scute broken off. Photo taken.
7817-18	70.3	Deep scratches, likely from shark attack, across several areas of the carapace.
7808-09	73.3	Healed pieces missing from trailing edge of right front flipper.
7844-45	76.0	Partly healed puncture, likely from spear penetration, in second right lateral scute.
9401-02	77.5	Healed piece missing from left hind flipper.
7848-50	78.6	Deep scratches, likely from shark attack, across several areas of the carapace. Fresh lacerations on left hind flipper.
7839-41	79.4	Deep scratches, likely from shark attack, across several areas of the carapace and on the top of the head.

Table 19.--Growth rates of seven immature green turtles recaptured at Palaau, Molokai.

Tag No.	Date tagged Date recaptured	Carapace length in cm: Straight	Carapace length in cm: Curved	Recovery interval (months)	Growth rate in cm/month: Straight	Growth rate in cm/month: Curved	Growth rate in cm/year: Straight	Growth rate in cm/year: Curved
7303-04	1/6/84 4/23/85	40.0	43.0	15.5	0.24	0.23	2.86	2.71
7301-02	1/5/84 4/23/85	42.0	44.5	15.5	0.15	0.16	1.86	1.94
7893-94	4/24/85 7/18/85	51.5	55.5	2.8	0.14	0.18	1.71	2.14
6376-77	8/30/82 4/23/85	--	57.5	31.8	--	0.33	--	3.96
8627-28	4/25/85 7/17/85	55.3	59.0	2.8	0.18	0.18	2.14	2.14
7917-18	4/24/85 7/17/85	57.2	60.6	2.8	0.07	0.14	0.86	1.71
7921-23	4/24/85 7/18/85	71.0	78.0	2.8	0.11	--	1.29	--
Mean growth rates					0.15	0.20	1.78	2.43

Table 20.--Homing behavior exhibited by 10 green turtles recaptured on Molokai.

Tag No.	Straight carapace length (cm)	Capture site and date	Release site and date	Recapture site and date	Interval (months)
7303-04	43.7	Palaau 1/6/84	Kawela 1/6/84	Palaau 4/23/85	15.5
7301-02	44.4	Palaau 1/5/84	Palaau 1/5/84	Palaau 4/23/85	15.5
7893-94	51.5	Palaau 4/24/85	Palaau 4/24/85	Palaau 7/18/85	2.7
8627-28	55.3	Palaau 4/25/85	Palaau 4/25/85	Palaau 7/17/85	2.7
7917-18	57.2	Palaau 4/24/85	Palaau 4/24/85	Palaau 7/17/85	2.7
8634-35	57.8	Palaau 4/24/85	Palaau 4/24/85	Kawela 6/29/85	2.0
7939-40	59.5	Palaau 4/11/85	Kaunakakai 4/11/85	Palaau 4/24/85	0.5
6376-77	63.3	Palaau 8/30/82	Palaau 8/30/82	Palaau 4/23/85	31.7
8847-48	67.0	Palaau 7/11/85	Kaunakakai 7/11/85	Palaau 7/19/85	0.3
7921-23	71.0	Palaau 4/24/85	Palaau 4/24/85	Palaau 7/18/85	2.7

Distances

Kaunakakai to Palaau = 8 km
Kawela to Palaau = 17 km
Kaunakakai to Kawela = 9 km

Table 21.--Results of turtle netting effort near the warmwater outfall in Kahului Bay, Maui.

Field study date 1985	Duration in hours	Length of nets (m)	Netting effort (meter-hours)	No. of turtles captured	Meter-hours per turtle
7 May	5	9	45	1	45
17 June	7	18	126	1	126
18 June	6	36	216	[1]2	108
19 June	6	36	216	[1]0	--
20 June	6	55	330	[2]4	82
Overall	30	--	930	8	117

[1]An additional turtle was captured by hand on each of these nights while skin diving in the warmwater outfall.

[2]Includes the recapture of a turtle originally tagged on 18 June 1985.

Table 22.--Biometrics of nine green turtles sampled near the warmwater outfall in Kahului Bay, Maui.

Tag No.	Carapace length		Carapace width		Plastron length (cm)	Tail length/ sex (cm)	Head width (cm)	Front flipper width (cm)
	Straight (cm)	Curved (cm)	Straight (cm)	Curved (cm)				
8456-57	44.8	47.0	35.7	41.5	35.4	6.5(?)	7.0	7.8
8479-81[1]	71.8	76.0	55.9	69.0	56.8	12.5(?)	10.5	12.9
72/0-72	78.3	82.5	59.3	77.5	64.2	25.0(M)	10.7	13.6
8476-78	80.4	--	62.3	--	66.9	13.7(F?)	11.5	12.9
8482-85	86.0	--	65.5	--	68.4	20.3(F)	11.8	15.5
8464-67	86.2	90.5	--	--	70.4	40.2(M)	12.2	14.8
8472-75	90.2	--	63.9	--	71.2	22.0(F)	11.8	14.8
8468-71[1]	92.0	--	69.2	--	72.7	20.0(F)	12.3	14.6
8486-88[2]	96.5	--	73.0	--	78.0	28.0(F)	14.1	16.6

[1]Captured by hand while skin diving at night near the warmwater outfall.

[2]Numerous small tumors present on most skin surfaces and both eyes. This turtle was found dead of unknown causes at Nehe Point, 23 July 1986, 2.2 km north of where it had been tagged on 20 June 1985.

Table 23.--Identification of stomach contents sampled from seven green turtles near the warmwater outfall in Kahului Bay, Maui.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
8456-57	44.8	*Pterocladia* sp.	T
		Laurencia sp.	T
8479-81	71.8	*L. nidifica*	50
		Amansia glomerata	25
		Acanthophora spicifera	25
		Chondrococcus hornemanni	T
		Ceramium sp.	T
		Codium edule	T
		Dictyota sp.	T
		Small crab	
		Terrestrial grass fibers	
		Sand	
7270-72	78.3 (M)	*C. edule*	99
		Antithamnion sp.	T
		Climacosphenia sp.	T
		Synedra sp.	T
8476-78	80.4 (F?)	*Codium edule*	99
		Acanthophora spicifera	1
		Amansia glomerata	T
		Champia parvula	T
		Laurencia nidifica	T
		Jania capillacea	T
		Pterocladia sp.	T
		Acrochaetium seriatum Boerg.	T
8482-85	86.0 (F)	*Acanthophora spicifera*	99
		Amansia glomerata	T
		Codium phasmaticum	T
8464-67	86.2 (M)	*C. edule*	95
		Acanthophora spicifera	T
		Hypnea musciformis	T
		Halimeda discoidea	T
		Red-orange paint chips	
		Small crab leg and eyes	
8472-75	90.2 (F)	*C. edule*	99
		A. spicifera	1
		Amansia glomerata	T
		Ahnfeltia concinna	T
		Hypnea pannosa	T
		Ceramium sp.	T

Table 24.--Injuries and abnormalities found on five green turtles near the warmwater outfall in Kahului Bay, Maui.

Tag No.	Straight carapace length (cm)	Description
8479-81	71.8	Hole in first right lateral likely caused by a spear or harpoon.
7270-72	78.3	Partially healed indentation 4.5 cm in diameter in third central scute of carapace. Possibly a gunshot wound that impacted underwater, or blow by a dull instrument.
8464-67	86.2	Thick mound of scar tissue around 1 cm diameter hole in right ventral region of neck. A likely spear puncture.
8468-71	92.0	Blind in right eye due to completely atrophied eyeball. Healed piece missing from right hind flipper.
8486-88[1]	96.5	Numerous tumors (fibropapillomas) on both eyes as well as the inguinal and axial regions. Healed pieces missing from the trailing edge of left front flipper.

[1]This turtle was found dead of unknown causes at Nehe Point on 23 July 1986, 2.2 km north of where it had been tagged on 20 June 1985.

Table 25.--Percent injuries and abnormalities found on different size classes of green turtles sampled on Oahu, Molokai, and Maui.

Location		Size class - straight carapace length (cm)					
		35-45	45-55	55-65	65-75	75-85	>85
Kawela Bay, Oahu	N = 34	14%	14%	0%	33%	0%	--
Palaau, Molokai	N = 133	0%	11%	8%	16%	67%	--
Kahului Bay, Maui	N = 9	0%	--	--	100%	50%	60%

Table 26.--Percent nutrient composition[1] of benthic algae collected near the warmwater outfall at Kahului Bay, Maui.

Algae (source)	Dry matter	Crude protein[3]	Ether extract	Ash	Neutral detergent fiber	[2]Acid detergent fiber	
						Permanganate lignin	Cellulose
Codium edule (near warmwater outfall)	7.4	10.7	0.5	57.0	26.6	3.4	6.9
C. edule (from channel 200 m offshore)	5.6	8.2	0.6	60.1	21.8	3.5	6.2
C. reediae (near warmwater outfall)	5.3	12.2	0.8	53.5	23.8	2.5	5.6
Acanthophora spicifera (near warmwater outfall)	6.8	23.2	0.1	45.3	23.1	6.8	8.9

[1]Reported on a dry matter basis as determined by the "proximate analysis" method commonly used for terrestrial animal forage.

[2]Present in benthic algae as a complex polysacchride; not true lignin or cellulose as found in terrestrial plants.

[3]Nitrogen × 6.25.

Table 27.--Mineral composition[1] of benthic algae collected near the warmwater outfall in Kahului Bay, Maui.

Algae (source)	Percentage					Parts per million			
	Ca	P	K	Mg	Na	Fe	Cu	Mn	Zn
Codium edule (near warmwater outfall)	5.68	0.11	2.88	1.84	>8.75	918	13	425	10
C. edule (from channel 200 m offshore)	1.68	0.09	4.45	1.98	>8.75	385	10	44	9
C. reediae (near warmwater outfall)	1.15	0.14	1.13	1.60	>8.75	251	34	244	21
Acanthophora spicifera (near warmwater outfall)	4.38	0.29	1.44	0.80	0.95	1,838	198	1,036	67

[1]Dry matter basis. Ca = Calcium; P = Phosphorus; K = Potassium; Mg = Magnesium; Na = Sodium; Fe = Iron; Cu = Copper; Mn = Manganese; Zn = Zinc.

Table 28.--Biometrics of green turtles sampled at Lanai and Maunalua Bay, Oahu.

Tag No.	Carapace length		Carapace width		Plastron length (cm)	Tail length (cm)	Head width (cm)	Front flipper width (cm)
	Straight (cm)	Curved (cm)	Straight (cm)	Curved (cm)				
Keomuku, Lanai								
7259-60	52.1	56.0	41.2	49.0	41.1	10.0	7.8	8.7
7264-66	62.3	66.0	48.7	59.5	50.8	11.0	6.3	9.7
7267-69	65.8	69.5	51.9	64.0	52.7	13.5	9.5	10.6
7261-63	75.8	81.5	57.3	76.0	61.3	15.0	10.3	12.3
Kuahua, Lanai								
8514-15	--	47.0	--	43.7	37.5	--	--	--
8516-18	--	72.5	--	66.0	57.0	--	--	--
Maunalua Bay, Oahu								
725/-58	39.2	40.1	34.8	40.0	31.1	7.0	6.3	6.2
7273-74	41.7	43.7	34.5	40.5	34.3	7.0	6.6	7.1
8451-52, 7275	62.2	66.5	49.2	61.5	49.8	13.0	9.6	10.4

Table 29.--Identification of stomach contents sampled from green turtles at Lanai and Maunalua Bay, Oahu.

Tag No.	Straight carapace length (cm)	Sample contents (%) T = trace	
Waiopae, Lanai (natural mortality on 28 April 1985)	38.9	*Acanthophora spicifera*	99
		Codium edule	1
		C. arabicum	T
		Chondrococcus hornemanni	T
Halepalaoa, Lanai (natural mortality on 4 May 85)	38.9	**Stomach contents**	
		Filefish bones	99
		Amansia glomerata	1
		Acanthophora spicifera	T
		Intestinal contents	
		Amansia glomerata	99
		Codium edule	1
		Acanthophora spicifera	T
		Dictyosphaeria versluysii	T
		Fish bones	
Keomuku, Lanai			
7259-60	52.1	*Amansia glomerata*	99
		Jania capillacea	T
		Acanthophora spicifera	T
		Ceramium sp.	T
7267-69	65.8	*Amansia glomerata*	99
		Hypnea cervicornis	T
		Jania capillacea	T
		Sargassum polyphyllum	T
		Amphipods	
		Copepods	
Kuahua, Lanai			
8514-15	[1]47.0	*Acanthophora spicifera*	90
		Hypnea musciformis	10
		Griffithsia sp.	T
		Ulva fasciata	T
8516-18	[1]72.5	*A. spicifera*	90
		Hypnea musciformis	5
		Ulva fasciata	5
Maunalua Bay, Oahu			
7257-58	39.2	*Codium edule*	67
		C. arabicum	33

[1]Curved length.

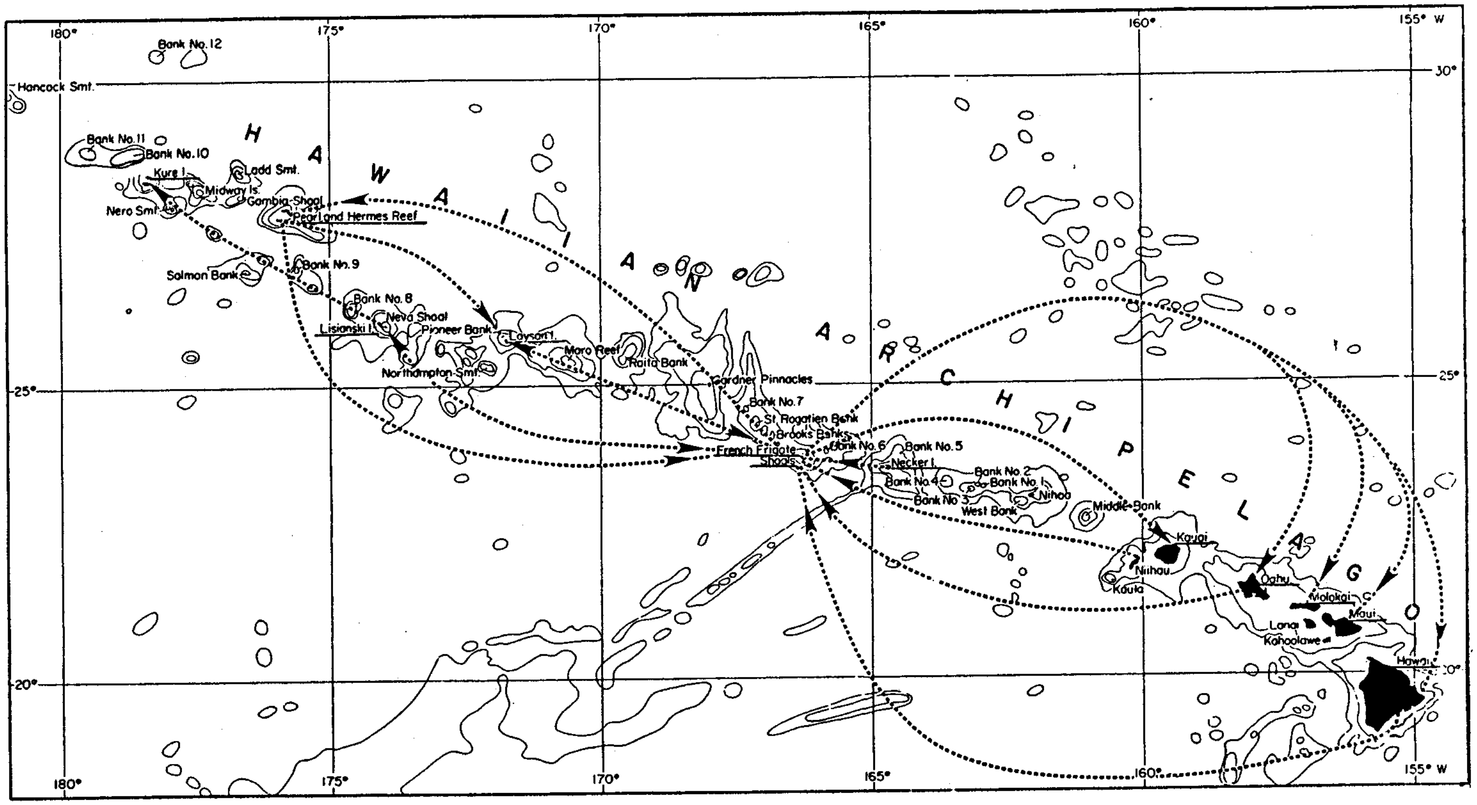


Figure 1.--Map of the Hawaiian Archipelago showing long-distance reproductive migrations of green turtles to and from French Frigate Shoals as documented by tagging studies.

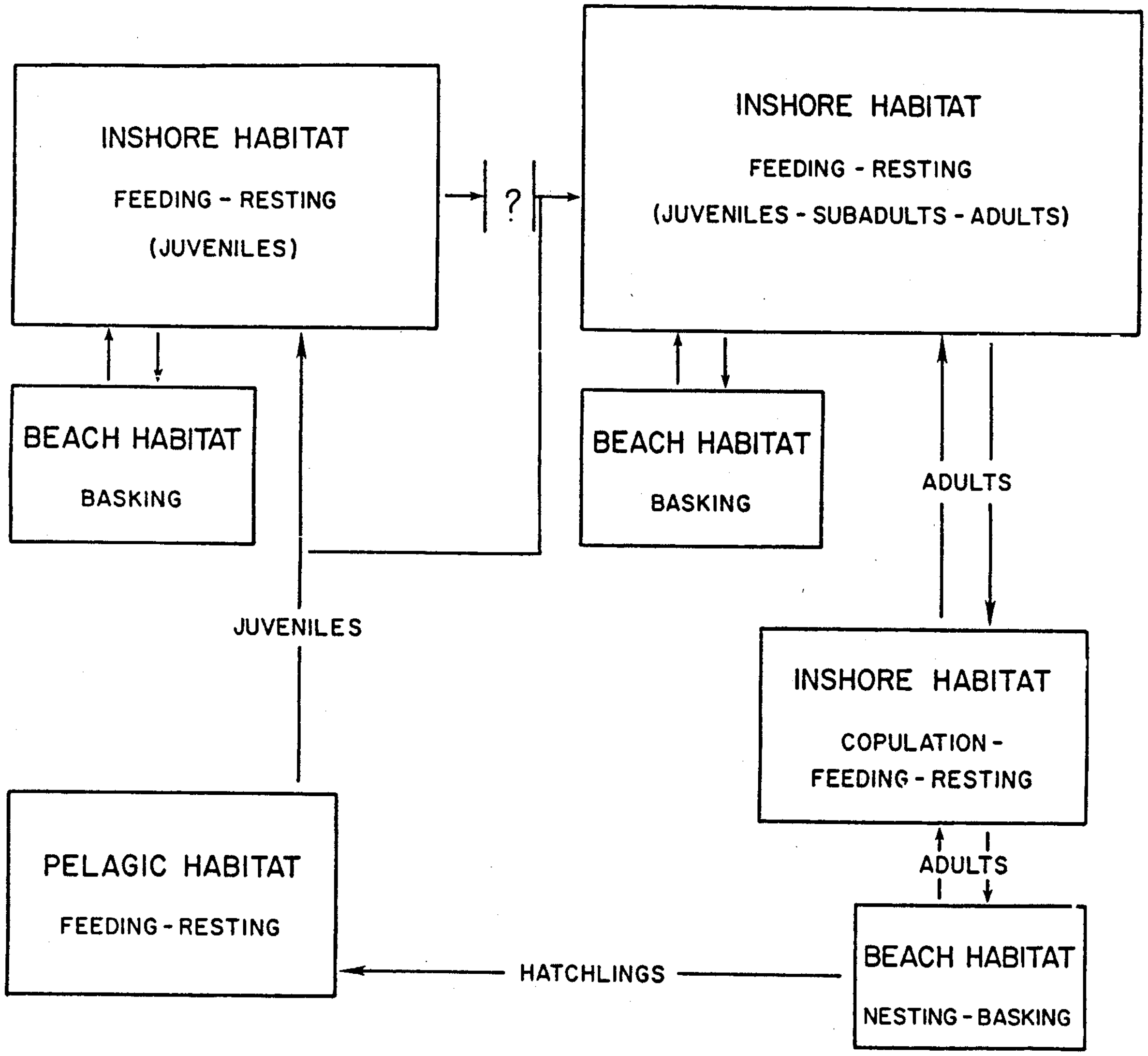


Figure 2.--Life history and habitat model for the Hawaiian green turtle.

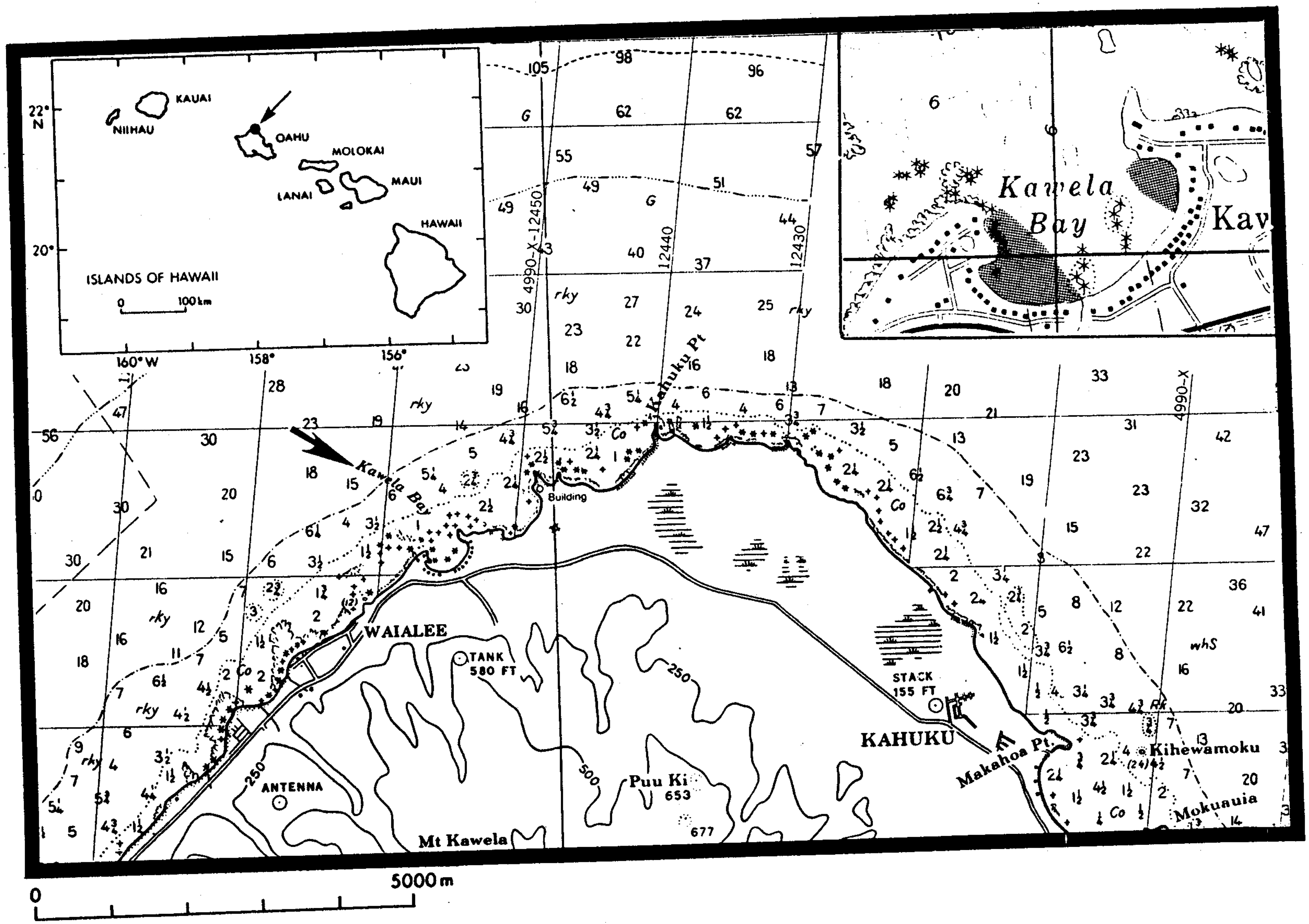


Figure 3.--Kawela Bay, Oahu, lat. 21°24'N, long. 158°01'W. Adapted from NOAA chart 19357 (depth in fathoms). Inset shows the approximate areas where most turtles were seen.

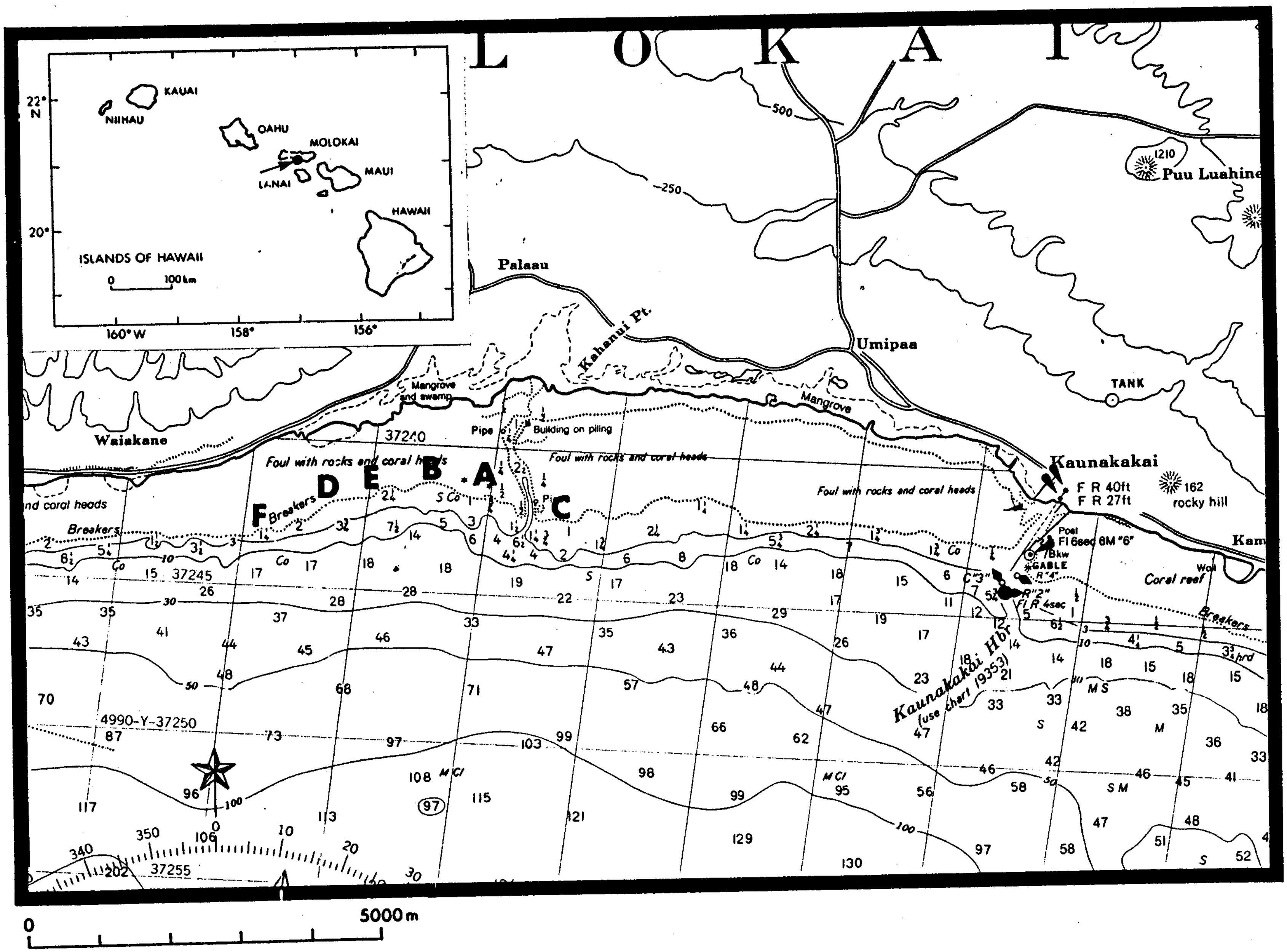


Figure 4.--Palaau, Molokai, lat. 21°06'N, long. 157° 07'W. Adapted from NOAA chart 19531 (depth in fathoms).

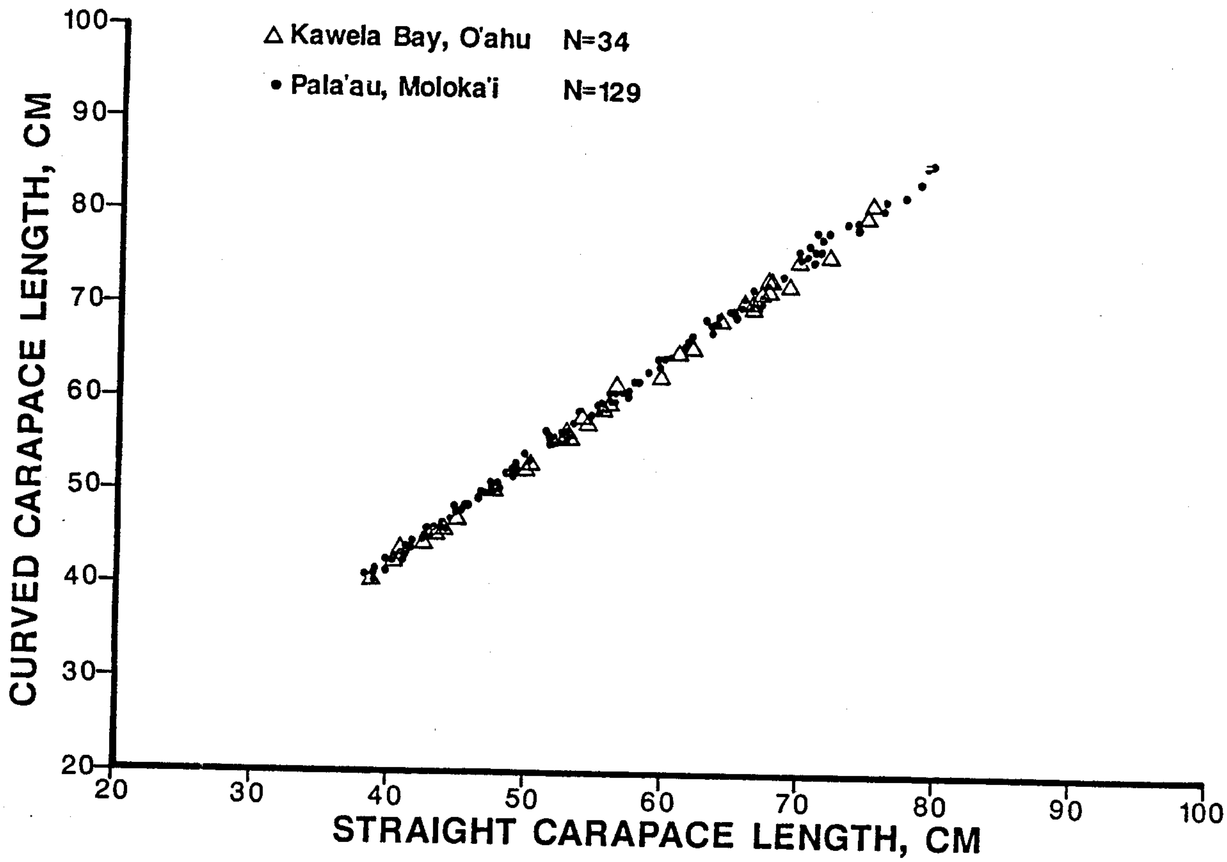


Figure 5.--Relationship of the straight and curved carapace length for 163 green turtles samples at Palaau, Molokai and Kawela Bay, Oahu.

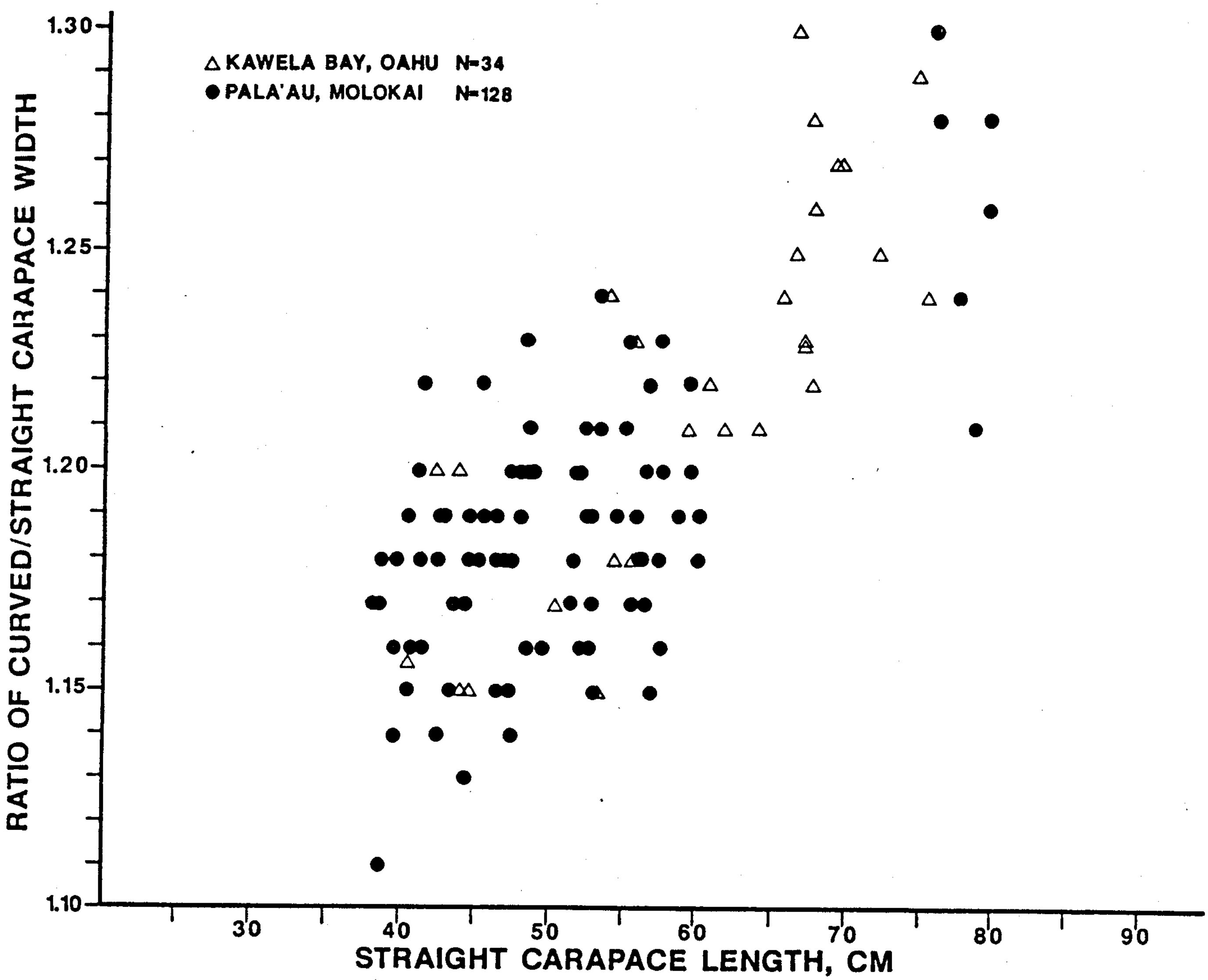


Figure 6.--Relationship of the straight carapace length and ratio of the curved/straight carapace width for 162 green turtles sampled at Palaau, Molokai and Kawela Bay, Oahu.

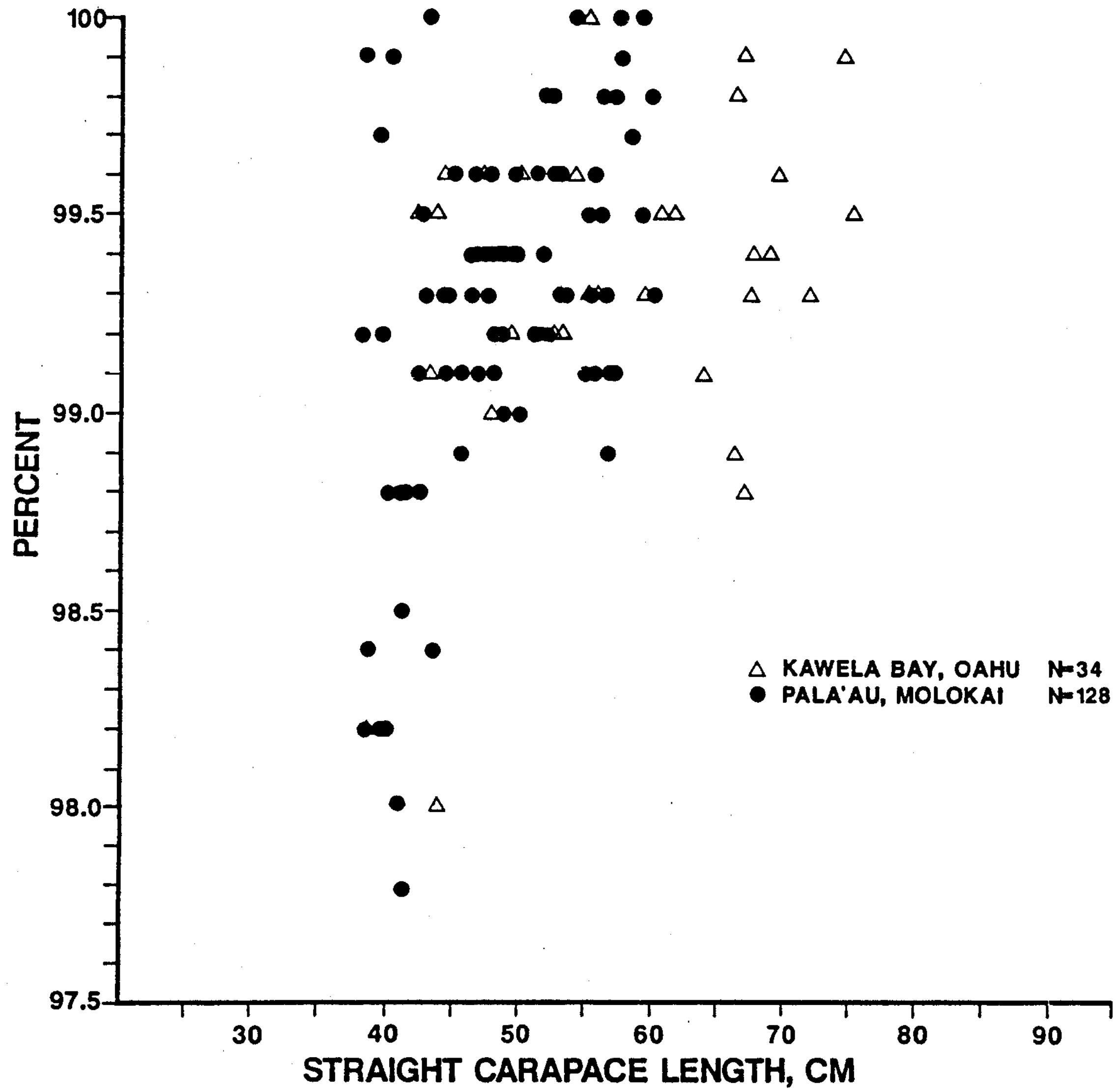


Figure 7.--Relationship of the standard straight carapace length and notch length for 162 green turtles sampled at Palaau, Molokai and Kawela Bay, Oahu. Notch length is expressed on the y-axis as a percentage of the standard length.

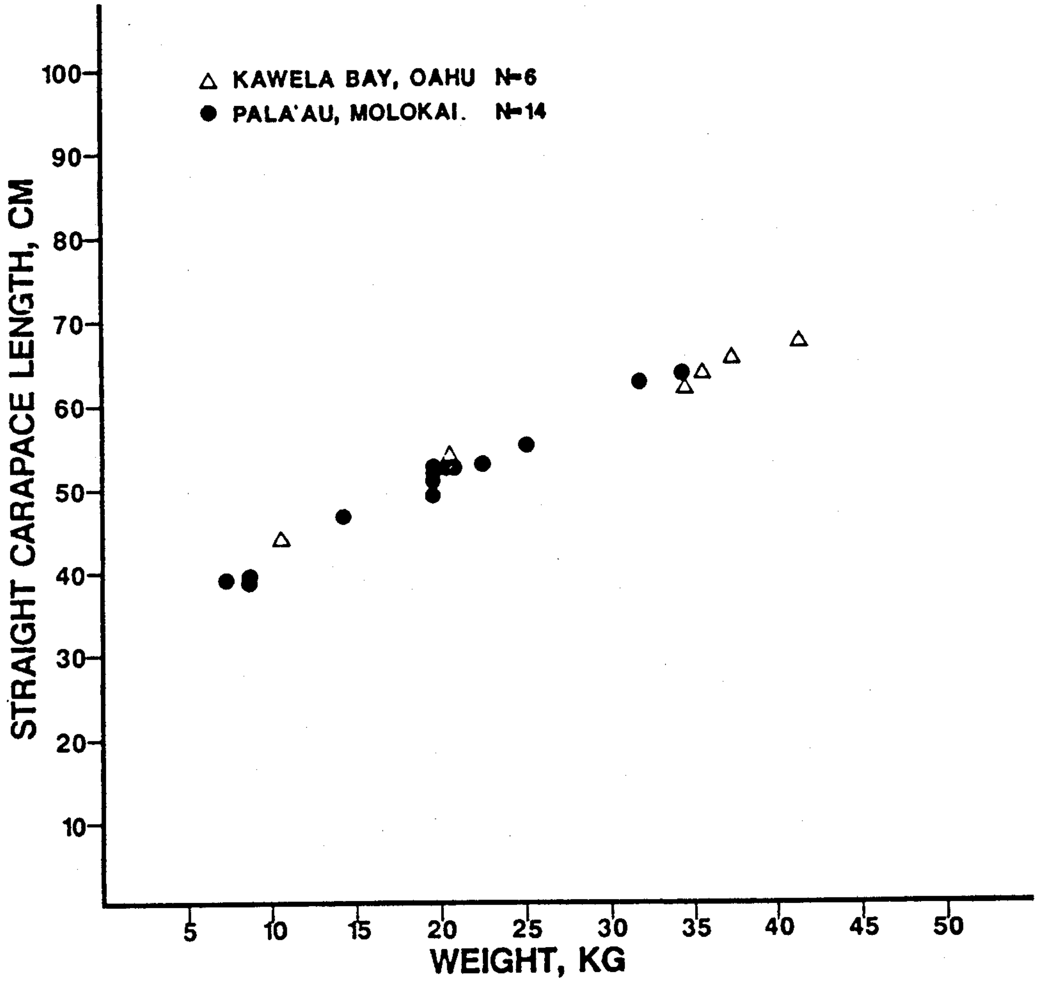


Figure 8.--Relationship of the weight and straight carapace length for 20 green turtles sampled at Palaau, Molokai and Kawela Bay, Oahu.

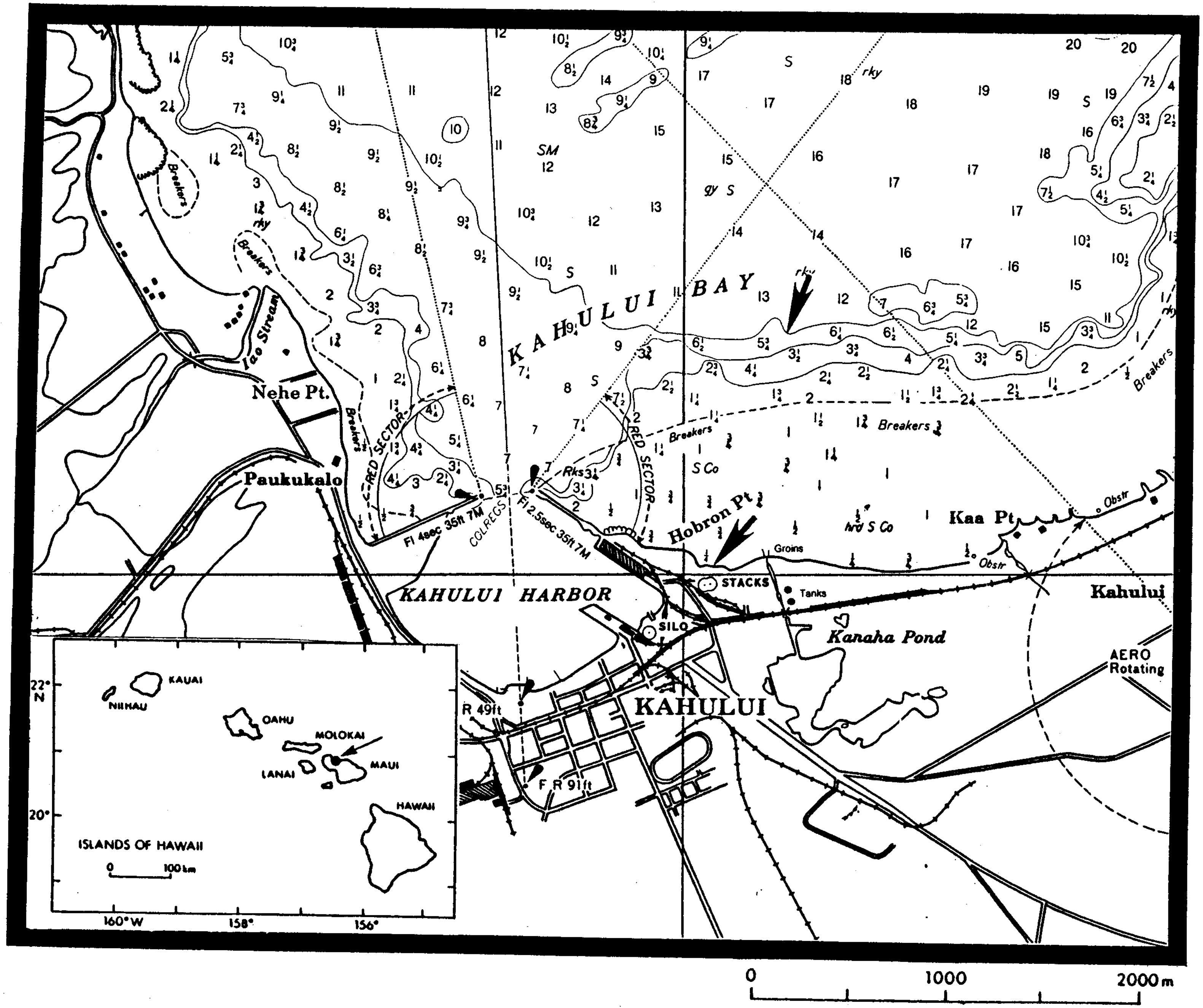


Figure 9.--Kahului Bay, Maui, lat. 20°54'N, long. 156°28'W. Adapted from NOAA chart 19342 (depth in fathoms).

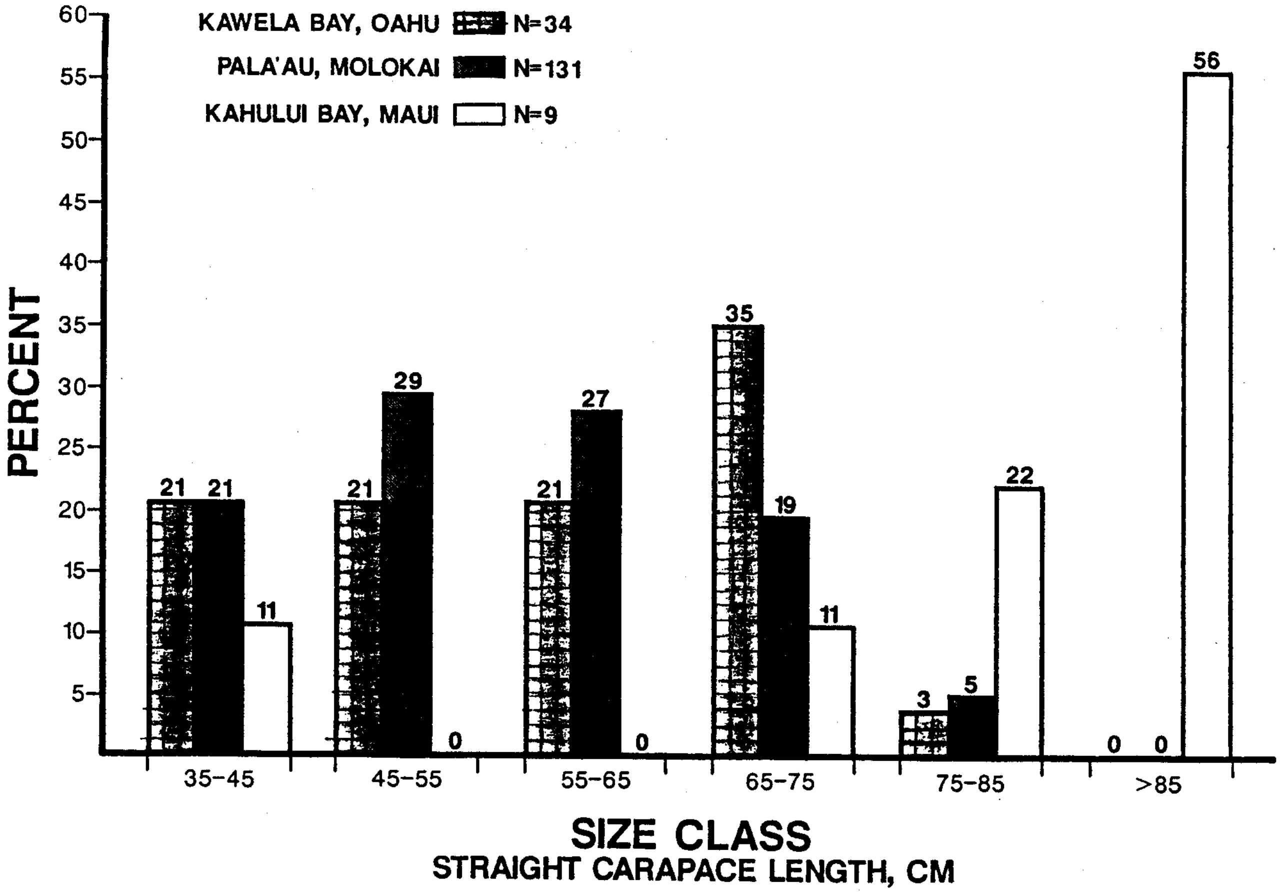
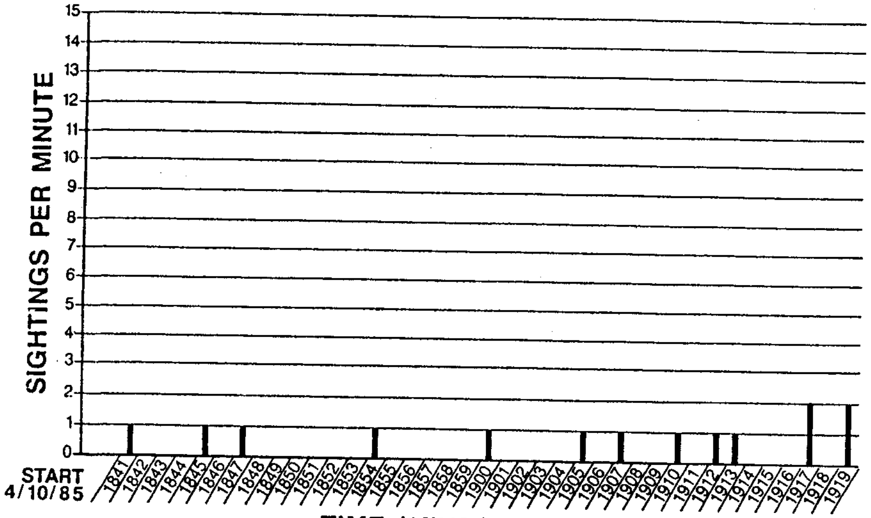


Figure 10.--Size classes in 10-cm increments of green turtles sampled at Kawela Bay, Oahu; Palaau, Molokai; and Kahului Bay, Maui.



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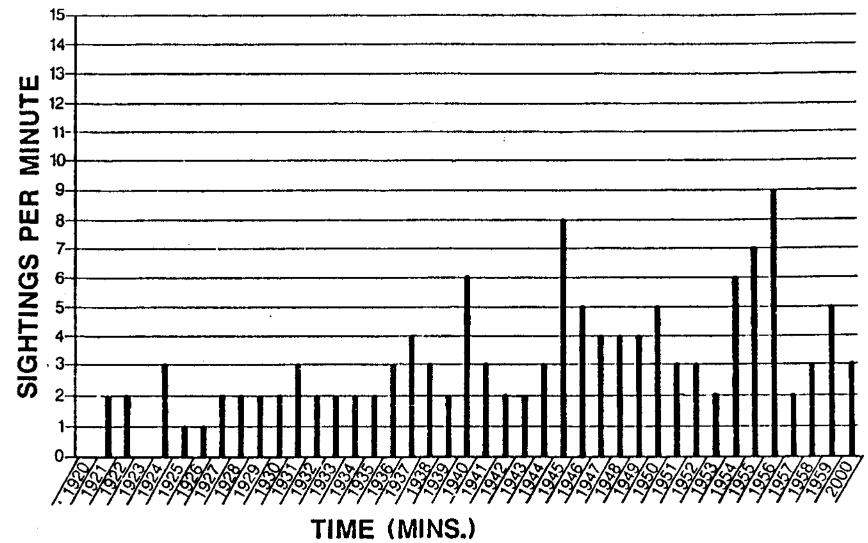
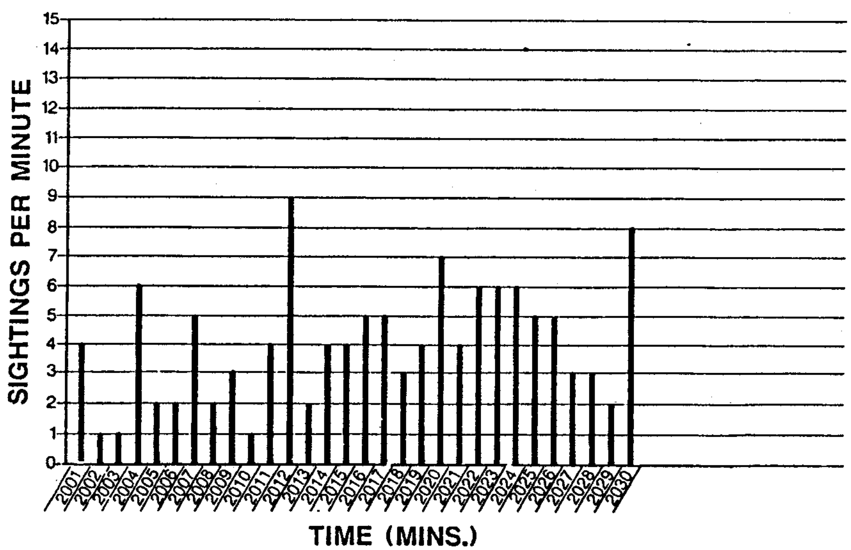
Sunset at 1850. Floodlight on at 1900. Brisk onshore tradewinds and choppy seas.



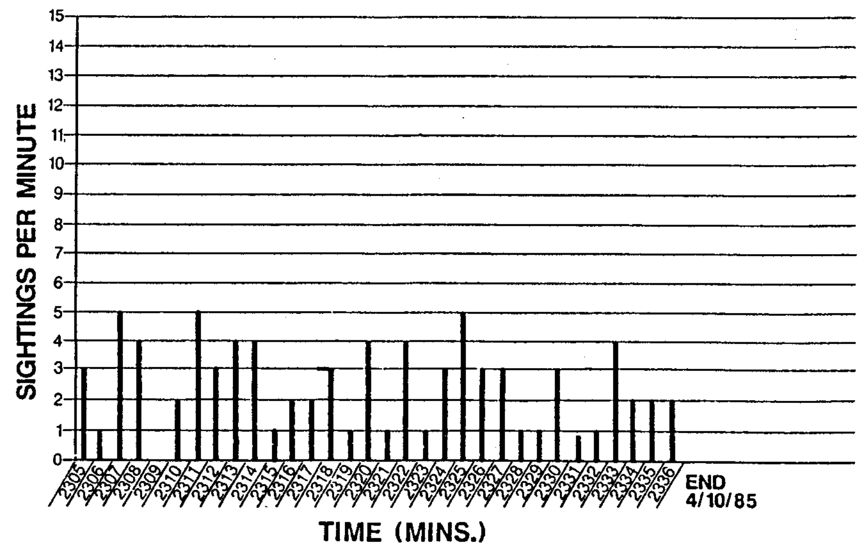
1a

End of observable twilight at 1930. High tide of 0.6 m (1.9 ft) at 2000.



1b

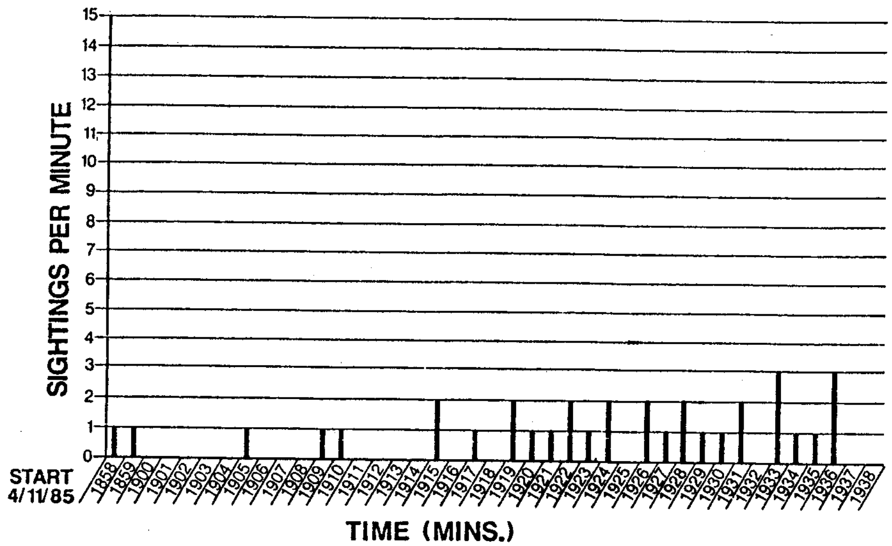
Three persons with rods and reels arrived at 2030 and commenced fishing from the elevated boulder embankment above the warmwater outfall. Counts not made from 2031 to 2304.



1c

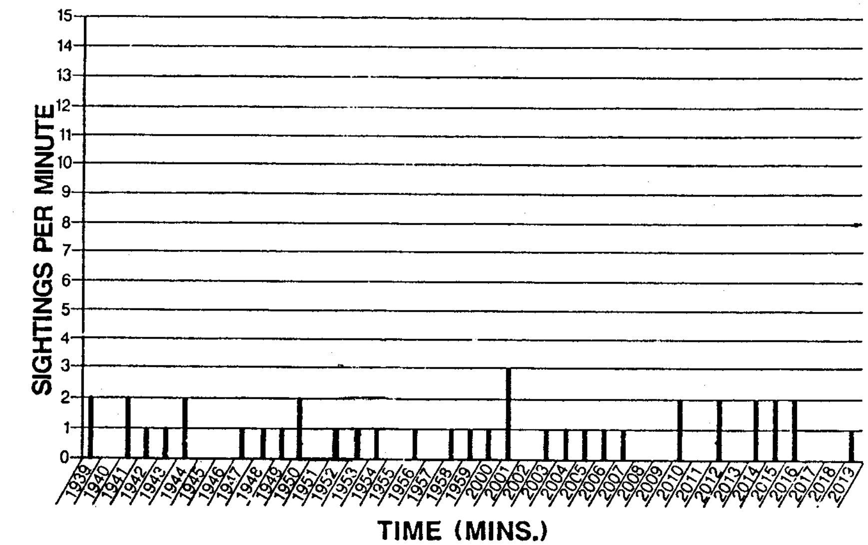
Fishermen departed at 2330.

Figure 11.--Sightings of green turtles surfacing to breathe near the warmwater outfall in Kahului Bay, Maui.



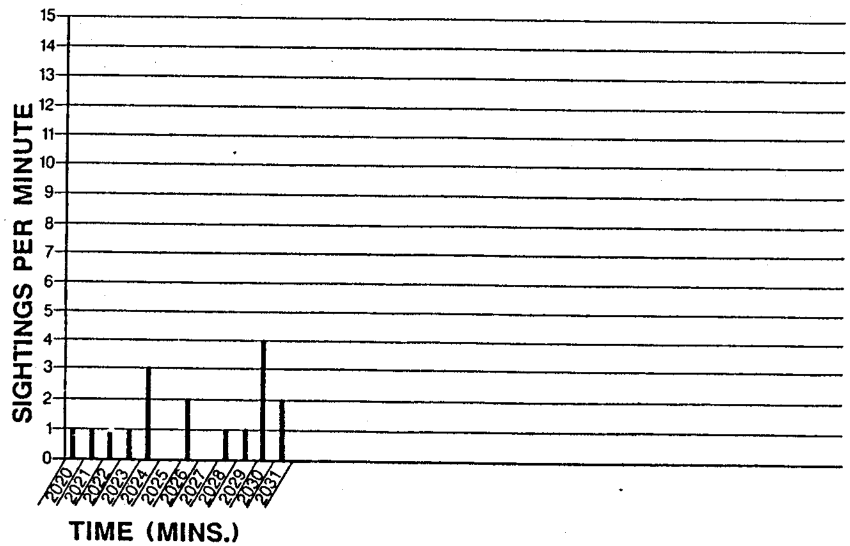
2

Sunset at 1850. Floodlight on at 1900. Gentle offshore winds and calm seas. Moon in last quarter. Fisherman casting from boulders at sea level right next to warmwater outfall.



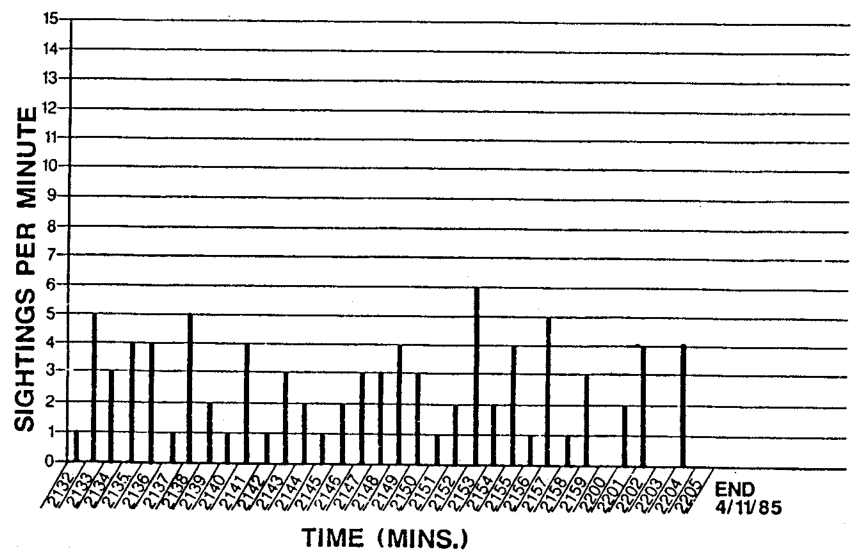
Fisherman departed. High tide of 0.5 m (1.8 ft) at 2045. End of observable twilight at 1930.

2a



No counts made from 2032 to 2131.

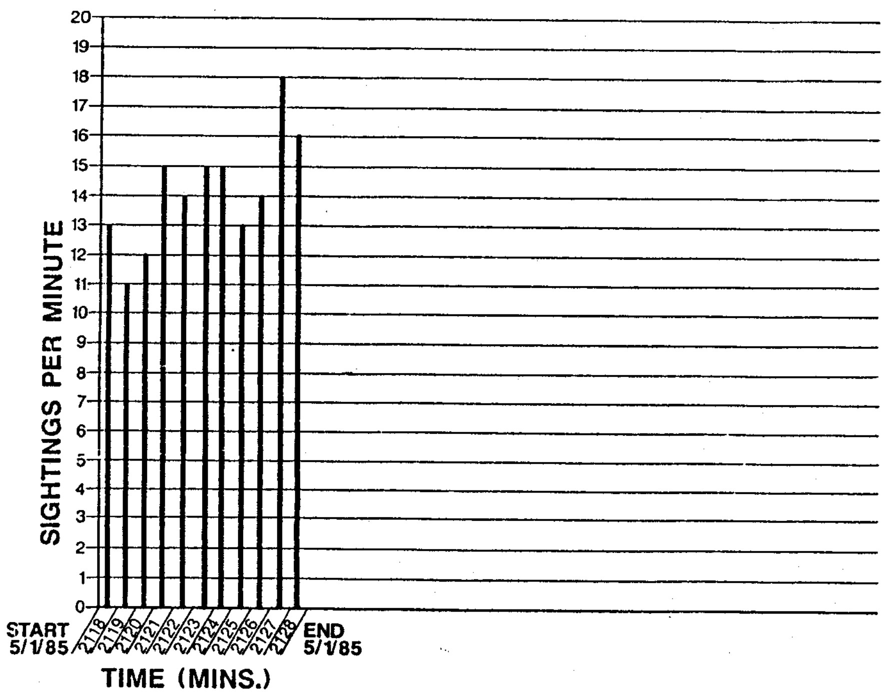
2b



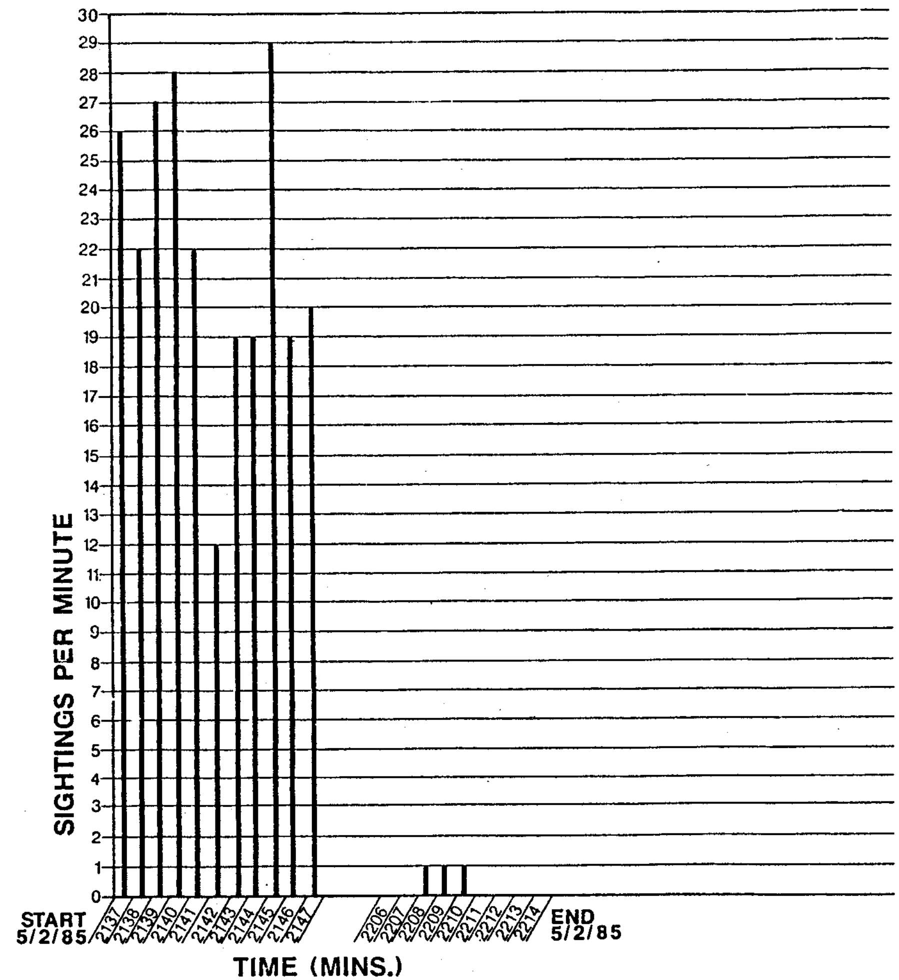
Several people fishing from elevated embankment 50 m to the east of warmwater outfall.

2c

Figure 11.--Continued.

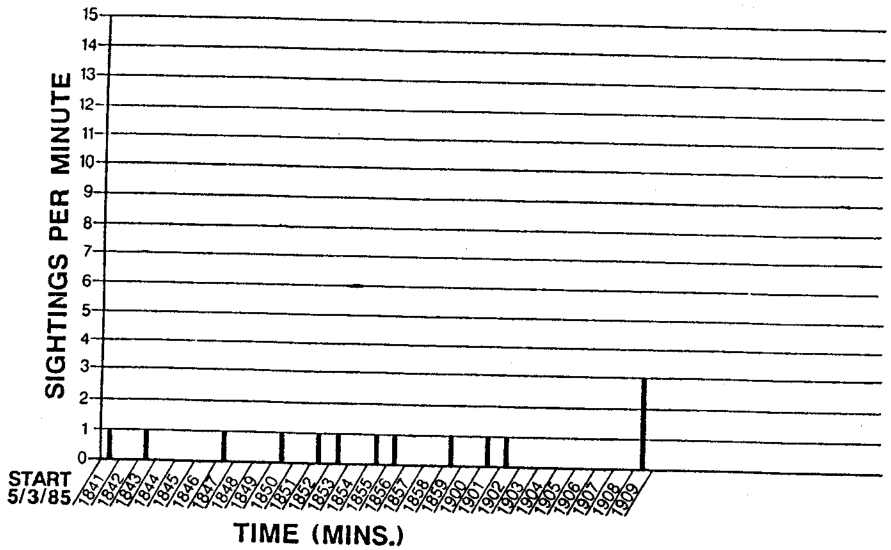


Floodlight on. High tide of 0.4 m (1.3 ft) at 2330. Low tide of 3 cm (0.1 ft) at 1815. **3**



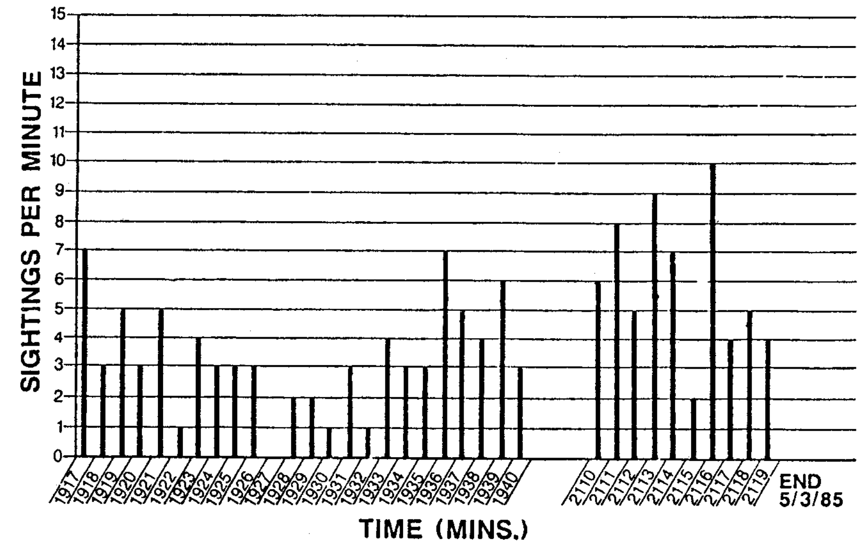
Floodlight on. High tide of 0.4 m (1.4 ft) at 0030 (3 May). Low tide of 0 m at 1900 (2 May). Light winds and calm seas. Skin diving survey was made by one person in the warmwater outfall from 2148 to 2205. **4**

Figure 11.--Continued.



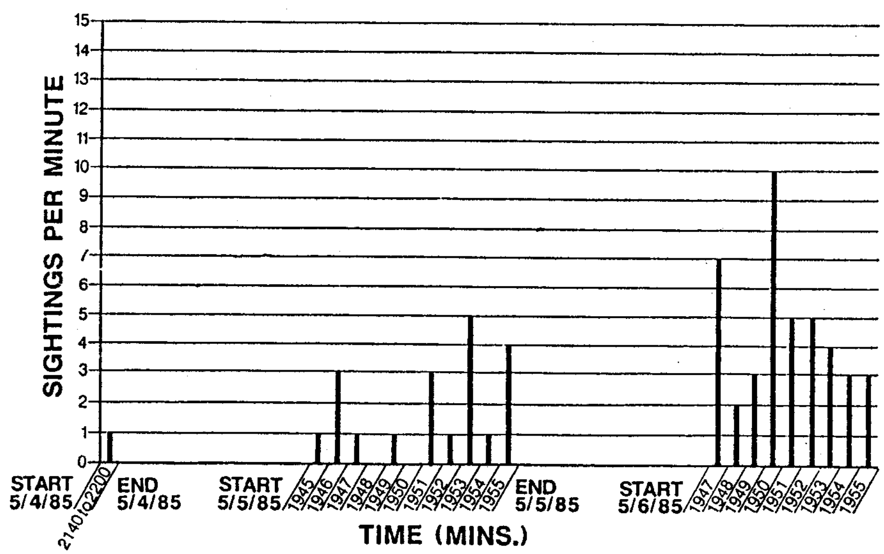
Sunset at 1900. Floodlight on at 1910. Low tide of 3 cm (0.1 ft) at 1930. Full moon occurred on the following night (4 May).

5



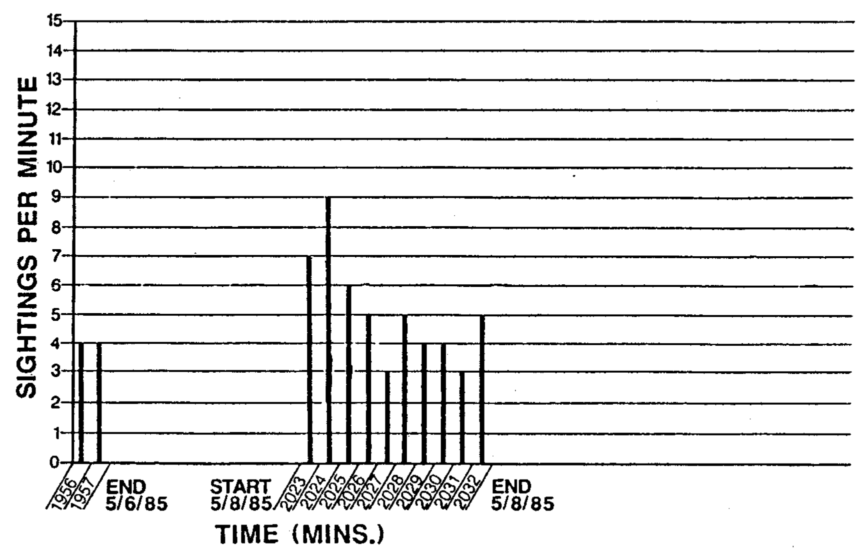
Moderate onshore winds with choppy seas. End of observable twilight at 1940. Counts not made from 1941 to 2109.

5a



Two fishermen right next to warmwater outfall on 4 May. Floodlight on. Only one sighting made during 20 min of observations. Fishermen likely present earlier in the evening on 5 May. Light winds and calm seas on 5 and 6 May. Floodlight on both nights.

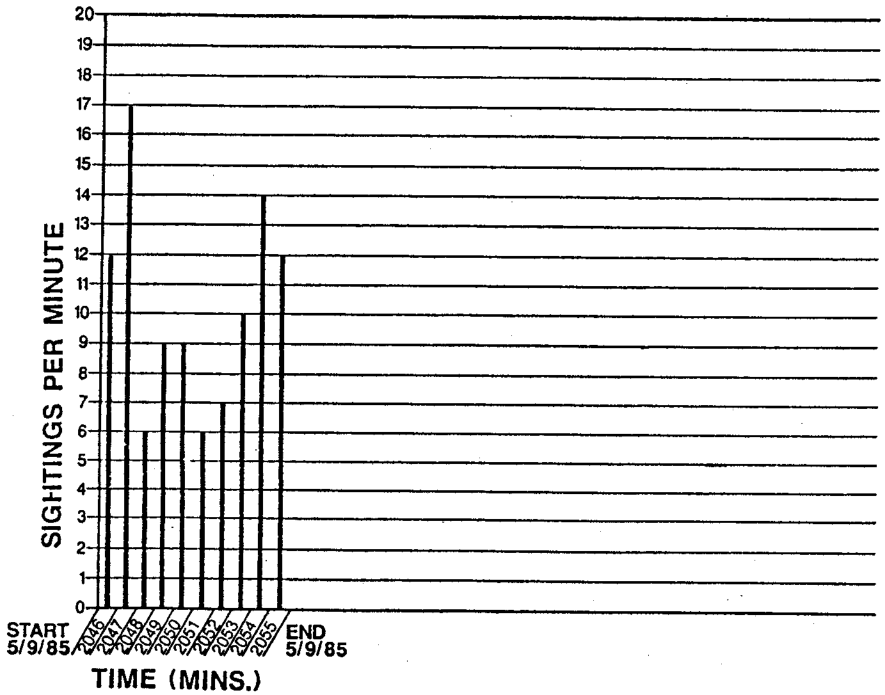
6



Moderate onshore tradewinds on 8 May. Floodlight on.

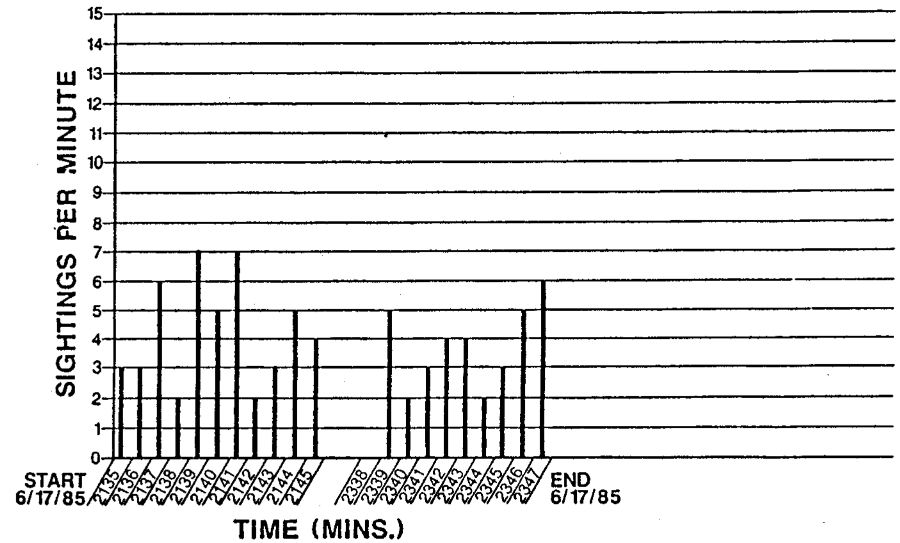
6a

Figure 11.--Continued.



Floodlight on. Brisk onshore tradewinds. High tide of 0.6 m (1.9 ft) at 1900. Moon in last quarter.

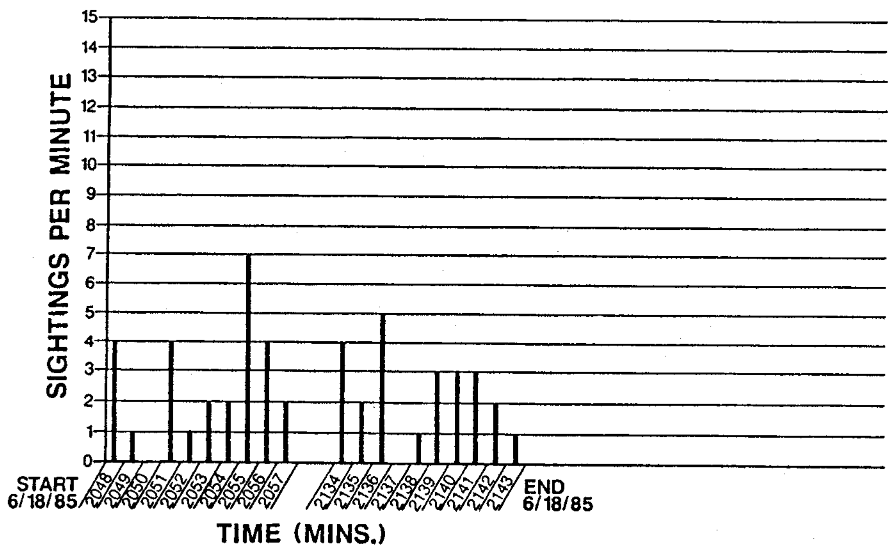
7



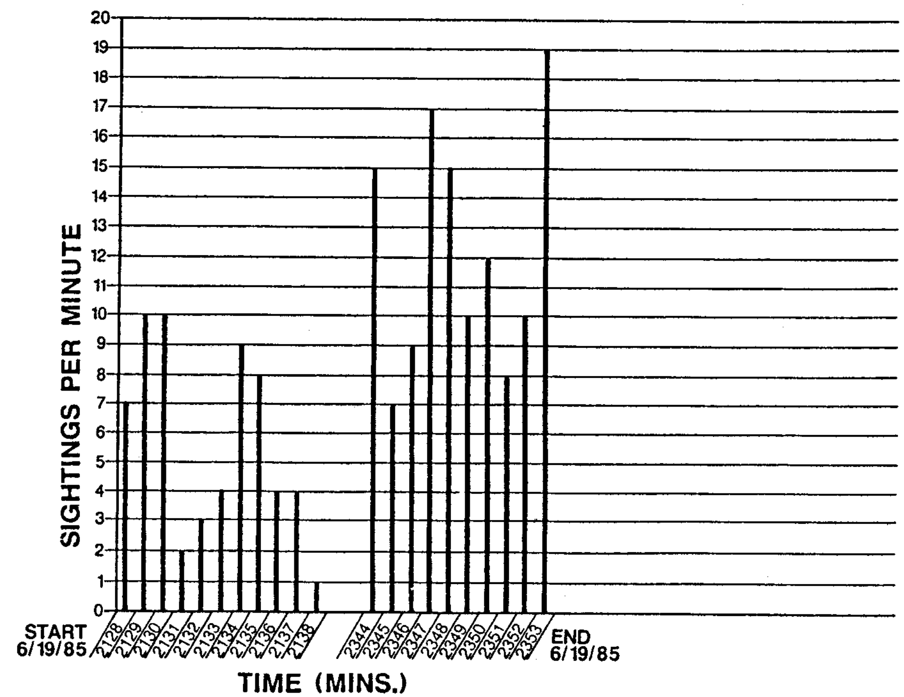
Large-mesh tangle net set by warmwater outfall from 1800 17 June to 0100 18 June. One turtle captured. Floodlight not turned on until 2335. No counts made from 2146 to 2337. Low tide of 0.6 m (0.2 ft) at 2200. Brisk onshore tradewinds.

8

Figure 11.--Continued.



9 Large-mesh tangle net set by warmwater outfall from 1800 to 2400. Two turtles captured. Floodlight not turned on until 2130. No counts made from 2058 to 2133. Brisk onshore tradewinds.



10 Large-mesh tangle net set by warmwater outfall from 1830 to 0108 (20 June). No turtles captured. Floodlight not turned on until 2340. No counts made from 2139 to 2343. Low tide of 6 cm (0.2 ft) at 2300. Brisk onshore tradewinds.

Figure 11.--Continued.

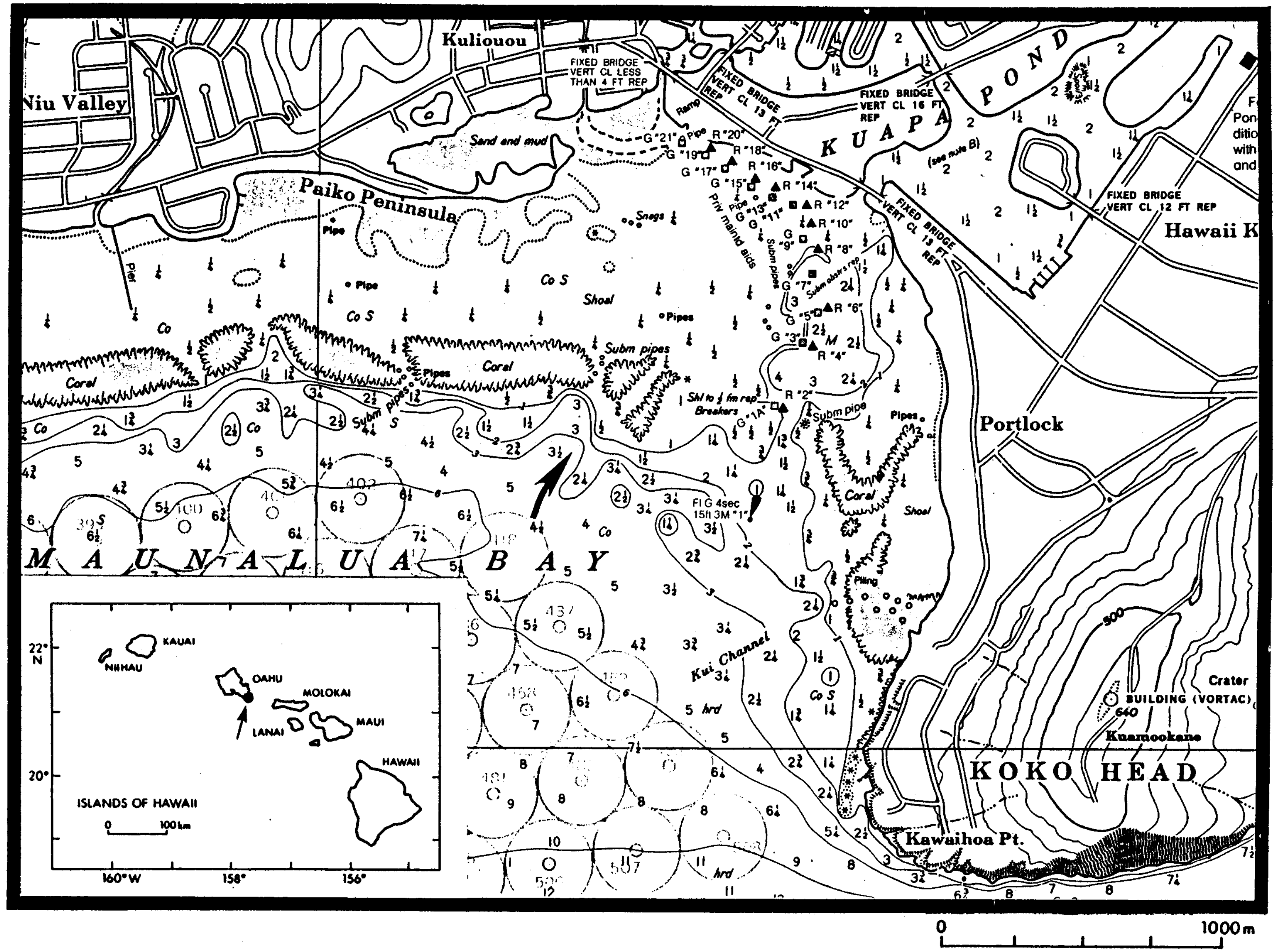


Figure 12.--Maunalua Bay, Oahu, lat. 21°17'N, long. 157°45'W. Adapted from NOAA chart 19358 (depth in fathoms).

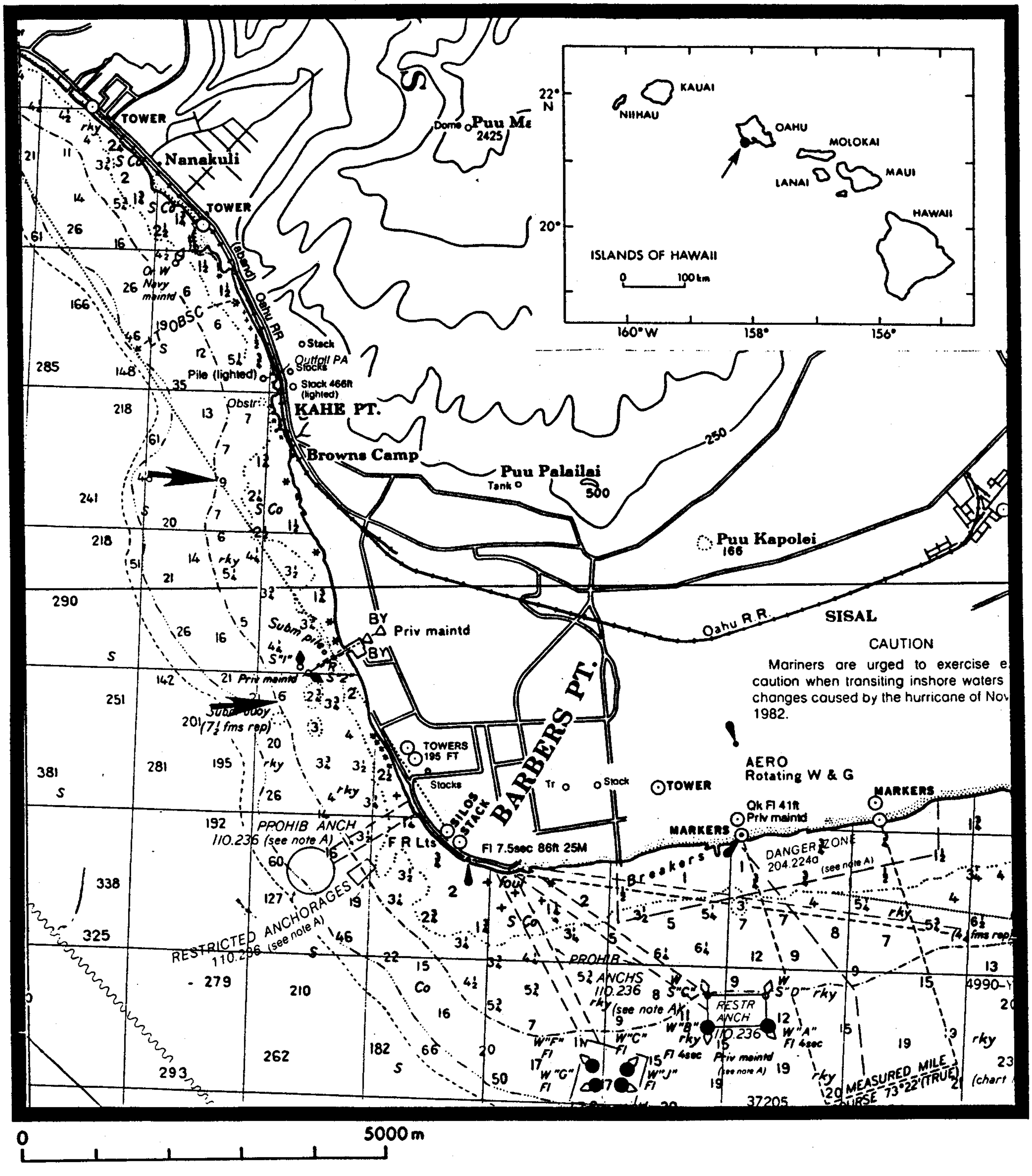


Figure 13.--West Beach, Oahu, lat. 21°21'N, long. 158°08'W. Adapted from NOAA chart 19357 (depth in fathoms).

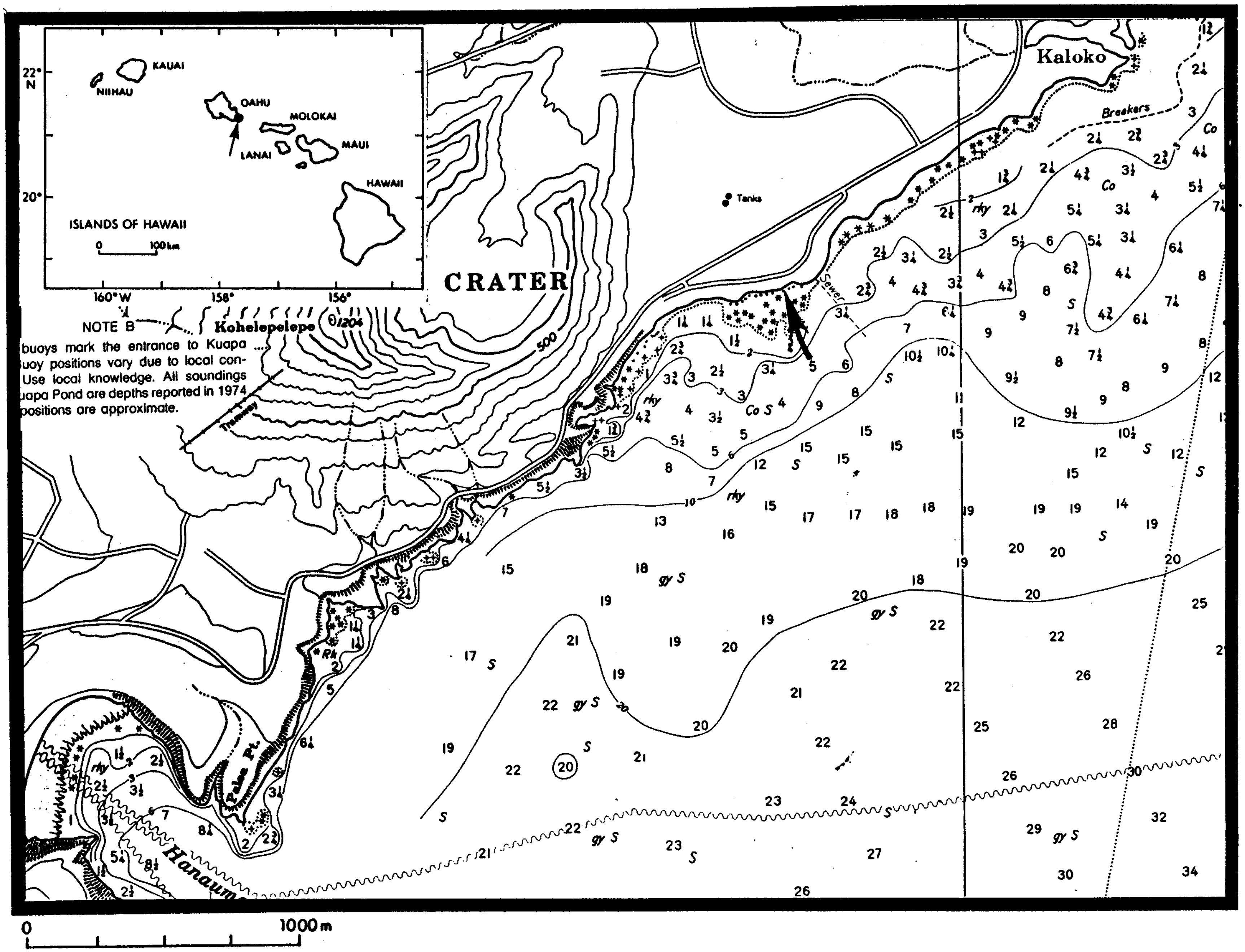


Figure 14.--Sandy Beach, Oahu, lat. 21°17'N, long. 157°41'W. Adapted from NOAA chart 19358 (depth in fathoms).

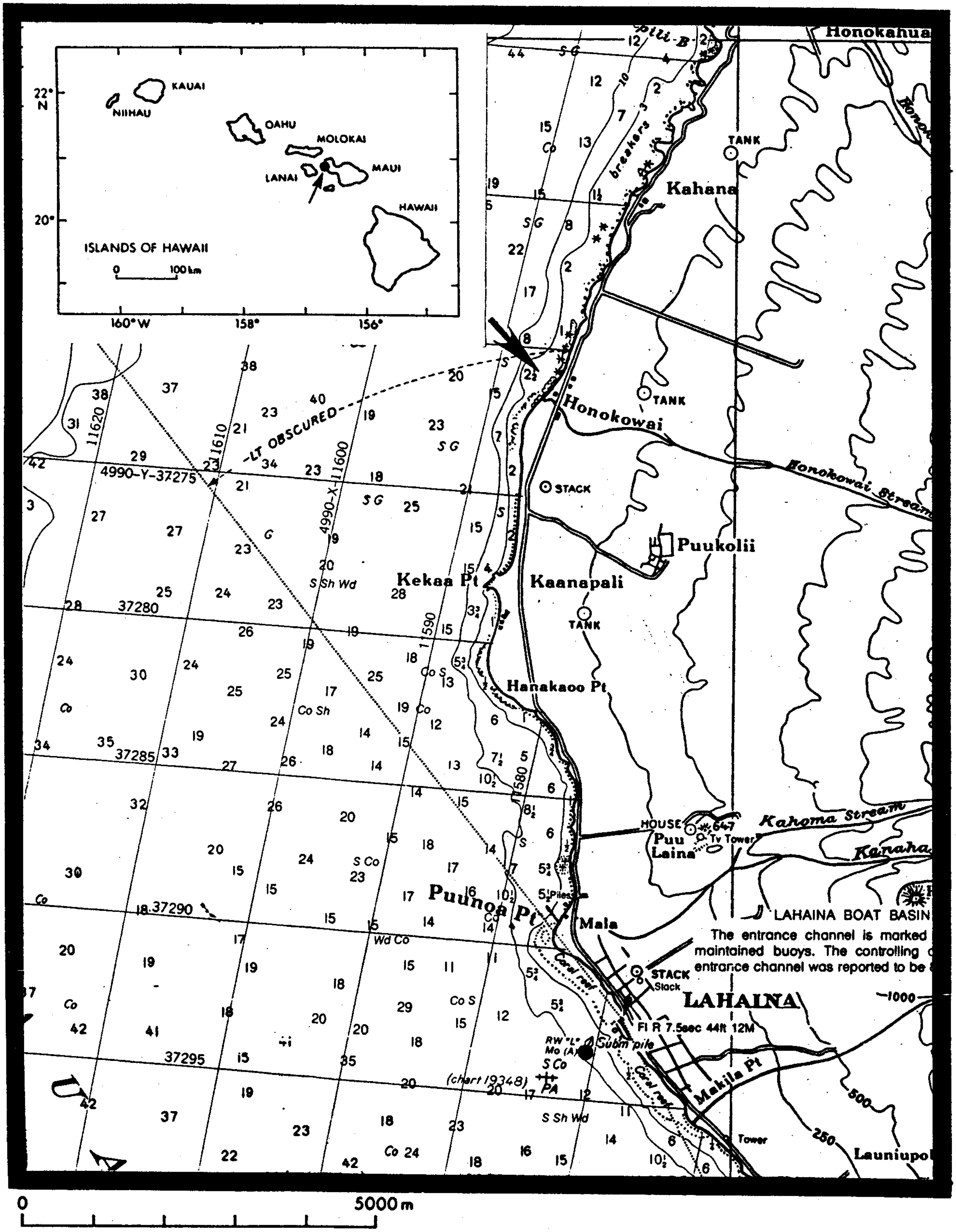


Figure 15.--Honokowai, Maui, lat. 20°57'N, long. 156°42'W. Adapted from NOAA chart 19348 (depth in fathoms).

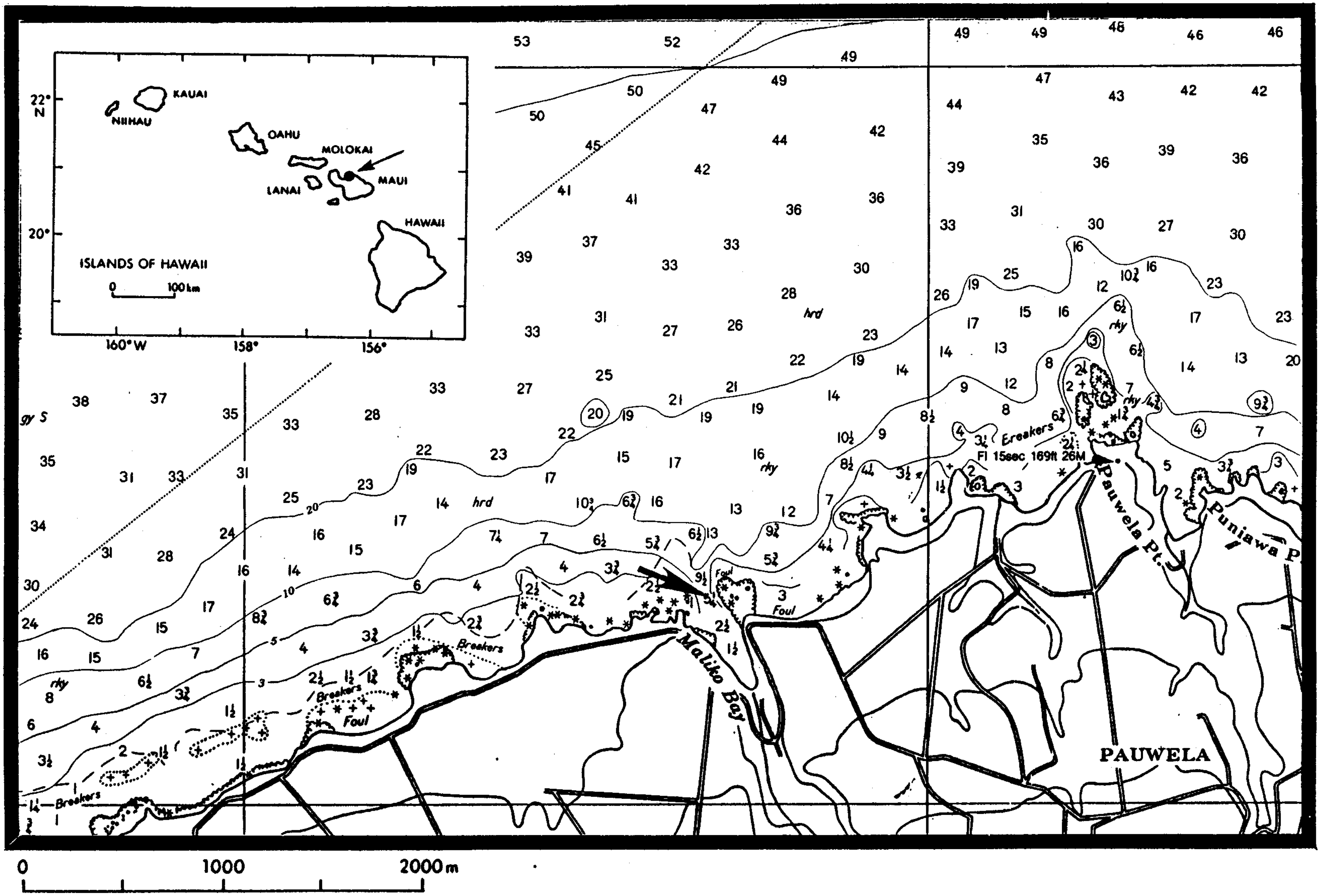


Figure 16.--Maliko Bay, Maui, lat. 20°49'N, long. 156°38'W. Adapted from NOAA chart 19342 (depth in fathoms).

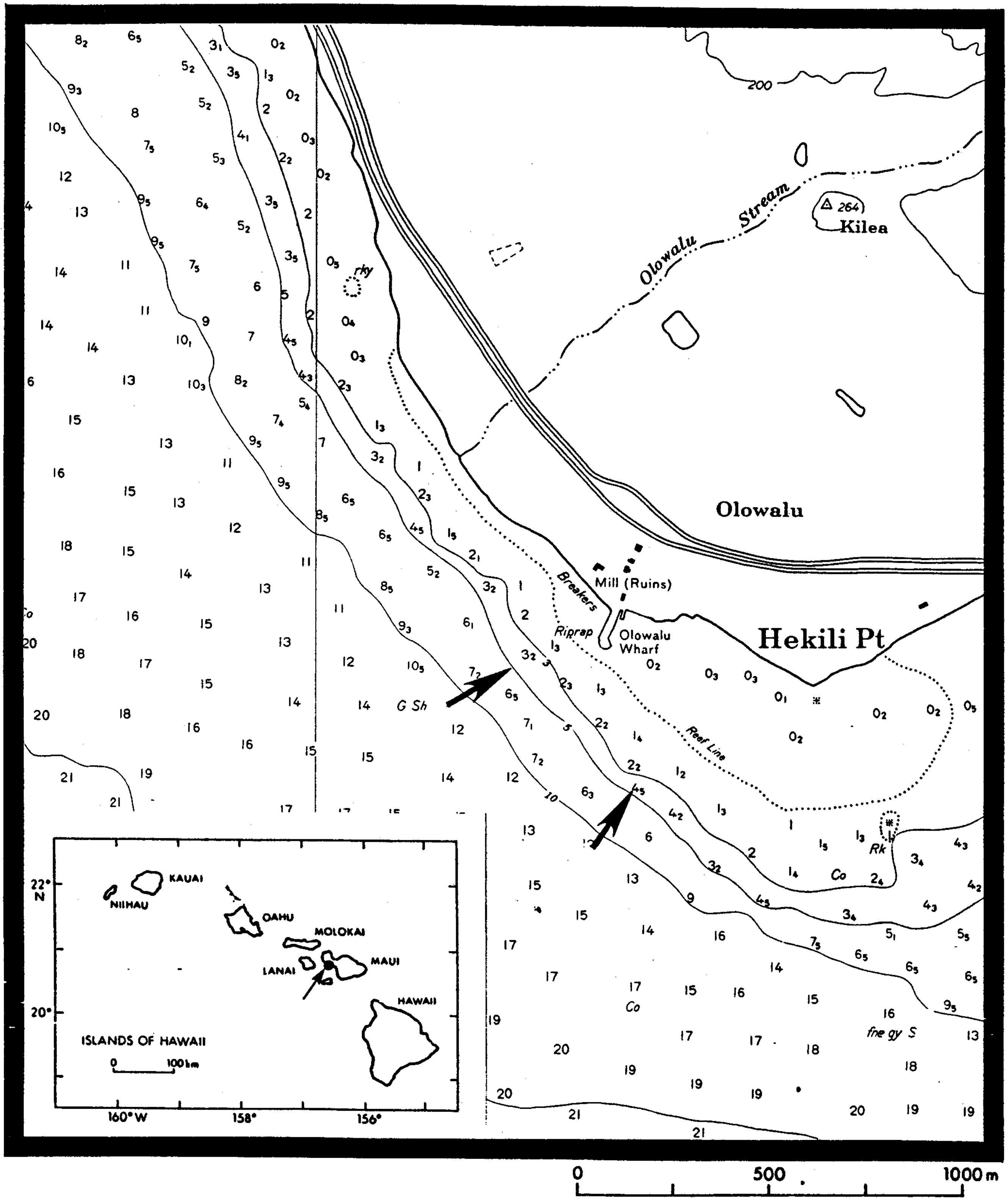


Figure 17.--Olowalu, Maui, lat. 20°49'N, long. 156°38'W. Adapted from NOAA chart 19348 (depth in fathoms).

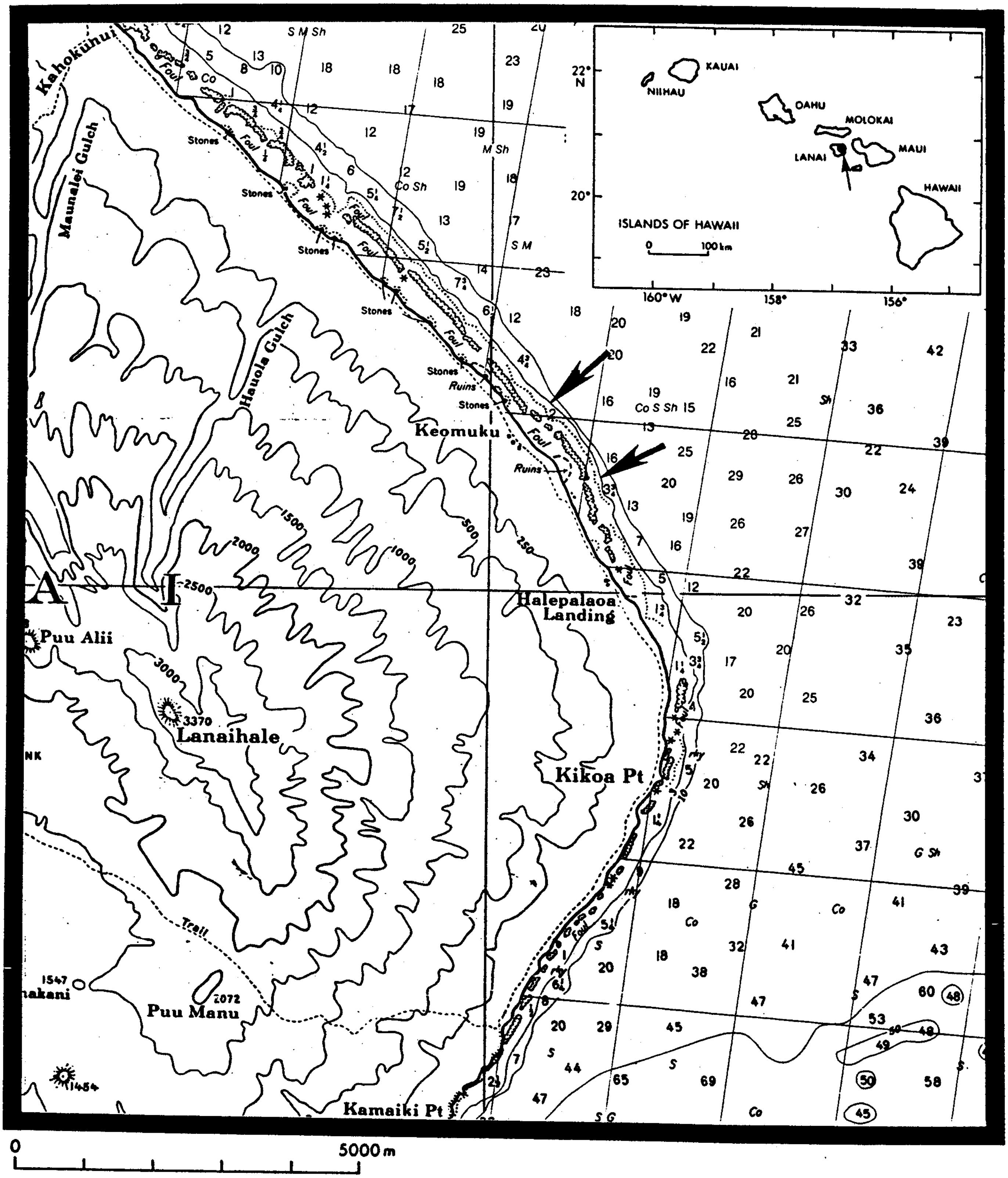


Figure 18.--Keomuku, Lanai, lat. 20°51'N, long. 156°50'W. Adapted from NOAA chart 19347 (depth in fathoms).

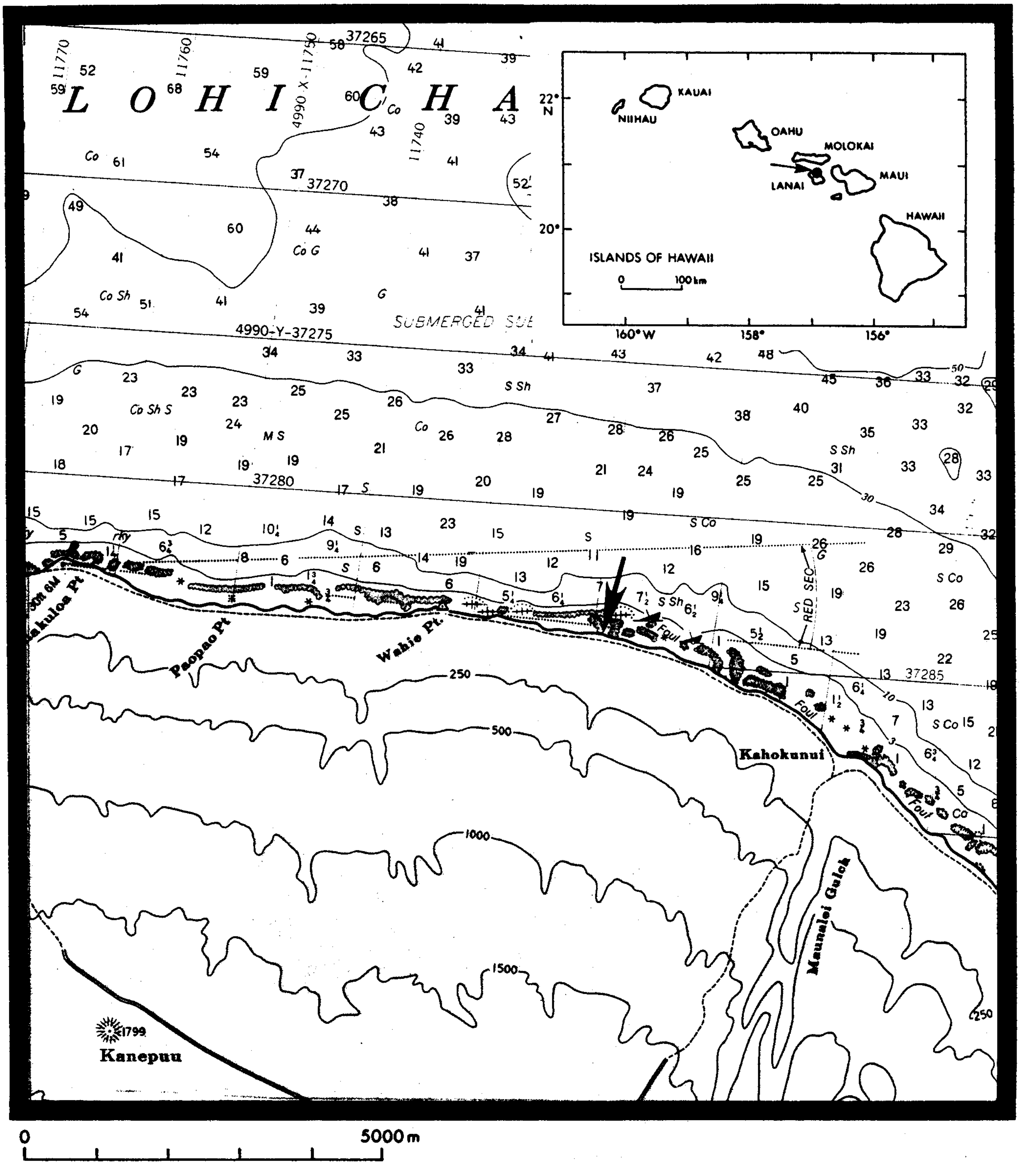


Figure 19.--Kuahua (Shipwreck Beach), Lanai, lat. 20°55'N, long. 156°55'W. Adapted from NOAA chart 19351 (depth in fathoms).

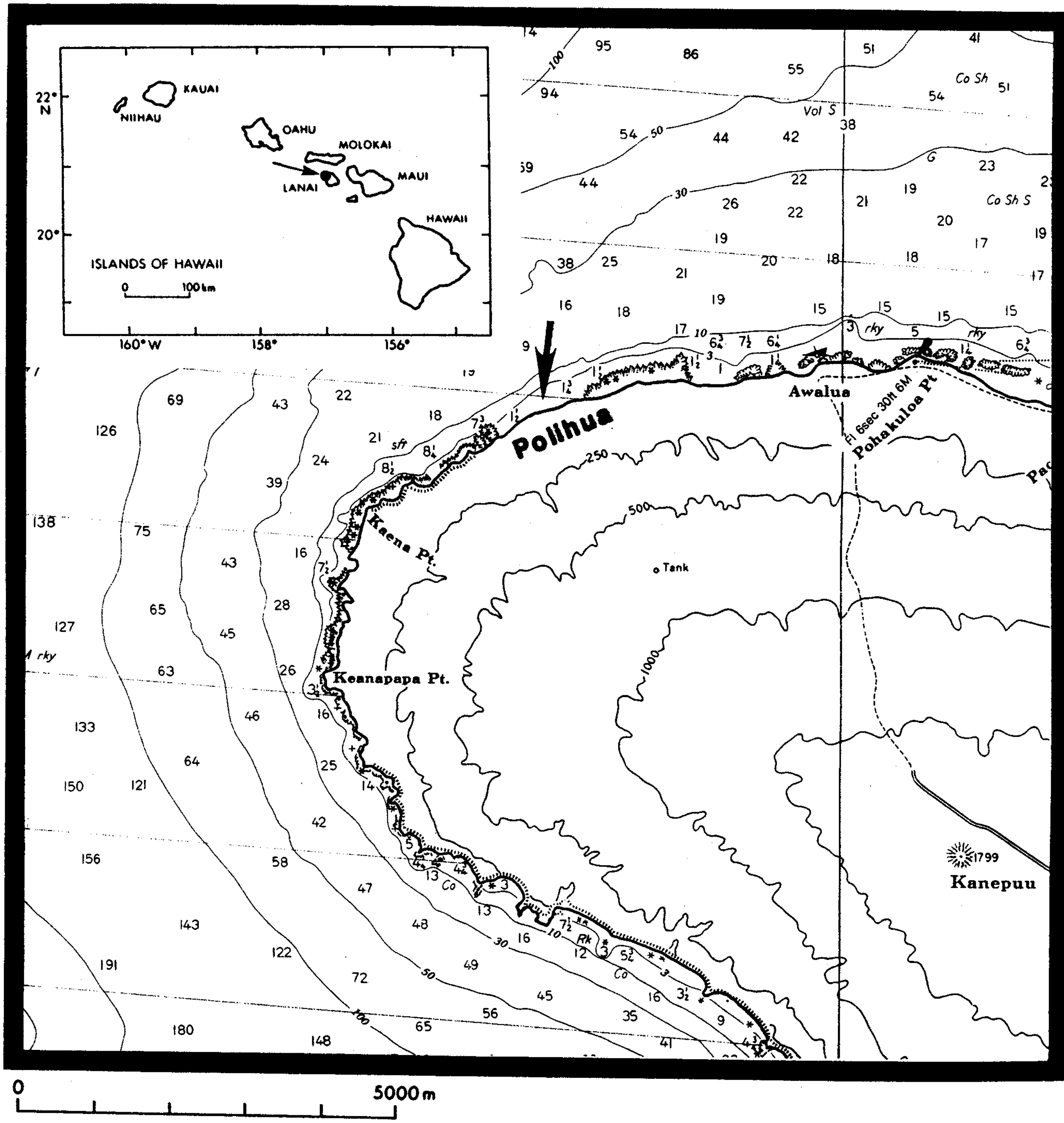


Figure 20.--Polihua Beach, Lanai, lat. 20°55'N, long. 157°03'W. Adapted from NOAA chart 19351 (depth in fathoms).

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